THE ADVANCEMENT OF SCIENCE

VOL. I. No. I OCTOBER, 1939

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NOTE ON COMMUNICATIONS TO THE SECTIONS

When the Dundee Meeting was brought to a close after three days, it was decided that all communications of which the delivery was unavoidably cancelled should be taken as read. Abstracts (or titles) of communications are therefore printed in these pages whether the comunications were delivered or not, and references to dates and hours, as furnished in the Journal issued at the Meeting, are excluded.

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It is intended to supply an index to the four parts in each year, in the July issue.

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HIS MAJESTY THE KING.

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PRESIDENT-ELECT (1940).

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Gen The Rt. Hon. J. C. Smuts, P.C., C.H., F.R.S. (1931).
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Prof. W. W. Watts, F.R.S. (1935).
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THE ADVANCEMENT OF SCIENCE

INTRODUCTION

The British Association was born of the period of reconstruction which followed the Napoleonic wars; it has been in a sense reborn of the period since the war of 1914–18. In 1919 there were those who viewed its future with some misgiving, fearing that its mechanism was outworn, and that its methods would prove to be unsuited to the advancement of science in (what was called) a changing world. But both mechanism and methods proved themselves adaptable to new demands, and it is certain that the Association has been during the past twenty years more steadily active in the successful prosecution of its objects than at any earlier time since the first few years of its establishment. This is not the place to offer chapter and verse for such an assertion; but it is made with confidence. And with a like confidence, another post-war period of rebirth is to be anticipated.

The meeting of the Association at Cambridge last year was fruitful in plans for the expansion of the Association's interests. At that meeting there was founded the Division for the Social and International Relations of Science, the activities of which, during the first year of its existence, are summarised in a short report included in these pages. At Cambridge also there was happily established a new and stronger liaison between the British and American Associations for the Advancement of Science, which resulted *inter alia* in the foundation of an annual lecture to be given in alternate years by an American speaker at a meeting of the British Association, and by a British speaker at a meeting of the American Association. The stage was set, at the recent meeting in Dundee, for Dr. Isaiah Bowman to deliver the first of these lectures. Alas, the meeting was dissolved before the date appointed for the lecture was reached. Dr. Bowman himself was on his way to Dundee—was indeed within a few miles of us—when news of the cancellation of the meeting reached him at Perth railway station, and he, as he has told us, crossed the platform to a train bound southward.

Another of the important new measures decided upon at Cambridge was the publication of the annual report of the Association in quarterly parts, under the title of The Advancement of Science, of which this is the first issue. It takes the place of the annual volumes which have been published by the Association without intermission from 1831 to 1938. It might have been imagined that such a series of volumes, if only for the sake of their not unimposing appearance upon the bookshelf, would not have been readily condemned to extinction. But for many years there has been evident a growing tendency to regard them as an incubus in the library, and as a place of premature burial for scientific communications unworthy of such a fate. Time and again it has been found that an inquirer into some special branch of science, desiring to possess a report or discussion thereon running to a few pages, was not unreasonably aggrieved when compelled to acquire a book of several hundred pages in which that particular matter happened to be interned. Quarterly publication should at least in a measure abolish that difficulty.

The Advancement of Science is intended in the future to make a wider appeal to lay readers of scientific matter than an annual volume could possibly make. But here the circumstances in which our first number appears compel the entry of a caveat. There is material in hand, from the Dundee Meeting of the Association, and from the activities of the Division for the Social and International Relations of Science during the past year, to provide for the issue of three or four parts in something approaching the form (though perhaps not in the bulk) that was intended. It may under certain conditions become necessary to defer subsequent issues due within the present year ; as to the future, it can only be said that at the moment of writing, preparations for the intended meeting of the Association next year in Newcastle-upon-Tyne are in abeyance.

Apart, however, from the reporting of the annual meetings, quarterly publication has been adopted with the intention of combating the belief, hitherto widely prevalent through the lack of an effective channel of communication, that the Association, after any one such meeting, lapses into a coma until it is time to awaken itself for the next. In normal circumstances, that is far from the truth—farther than ever during the past year, when the new Division, having been empowered to hold meetings of its own 'at times and in places other than those of the annual meetings of the Association,' has done so in Reading, in London, and in Manchester.

To what extent these and other activities may in the future be temporarily curtailed obviously cannot be forecast. At the moment routine business is in progress, some of it at the office in Burlington House, some at Down House in Kent. In case this should meet the eyes of persons unfamiliar with the story of Down House, it may be mentioned that it was the home of Charles Darwin, became the property of the Association by the gift of Sir Buckston Browne, and is maintained by us as a national memorial, freely open to the public in normal times. On August 24 last the word was given to close it and to take the precautions previously arranged ; the objects of historical value, Darwin's and others, were placed (it is hoped) in safety, and these lines are written in what once was Darwin's dining-room, now dismantled and in use as an office. Other rooms in the house are equipped as the first-aid post for the village of Downe, and as a hospital supply depôt, so that the Association and the public

owe a further debt of gratitude to Sir Buckston Browne for his gift, for reasons far other than those for which that gift was originally made.

The mention of that date, August 24, brings to mind the conditions in which the final preparations for the Dundee Meeting were carried out. There was then no question of abandoning the Meeting. The local committee, consisting of civic, university, and other representatives, already deeply concerned as some of them were with emergency duties, never hinted at such action. Their preparations, admirably conceived and executed, allowed of opening the meeting without the faintest sense of difficulty. The local support by way of temporary membership was far above the average, as the General Treasurer was able to state when, at the inaugural meeting, he announced the total number of tickets issued, a note as to which follows this introduction. It was pitiable that a meeting begun with these exceptional prospects of broadening the public interest in science should have been cut short, but it would have been more so had it not even been begun. An aphorism attributed to the late Lord Rutherford recalls itself to memory: 'It is better to have boomed and bust than never to have boomed at all.' If Michael Finsbury's sentiment that there is 'nothing like a little judicious levity' be admitted, that aphorism is profoundly true of the Dundee Meeting.

The meeting, then, opened as appointed on August 30 with the inauguration in the Caird Hall, the splendid building of which the name commemorates its donor, Sir James Caird, whom also the Association commemorates through the munificent monetary gift for research made to us by him in 1912, and recorded since in our annual accounts as the Caird Fund. The President, Sir Albert Seward, F.R.S., delivered the inaugural address which follows in these pages. Next day the Sections opened their sessions; the Division for the Social and International Relations of Science also held a meeting, and the reception by the Lord Provost and Corporation took place in the Caird Hall that evening, its brilliance unimpaired. On Friday, September 1, the Sections continued at work; the first of two intended special sessions on jute, organised with the interests of the great Dundee industry in mind, was held, and other incidental fixtures in the programme were carried out without restriction.

But by this time the components of the remaining days' programme were melting like icicles in a thaw: the evacuation of children from Dundee was ordered to begin, and excursions arranged for the Association on the Saturday must needs be curtailed; messages of inability to attend were accumulating from those expected to take part in the subsequent scientific transactions; many, already in Dundee, were being recalled to duties elsewhere. When the General Committee met on Friday afternoon, September 1, and heard reports of their difficulties from Sectional representatives, it became apparent that the meeting could not be carried through, and it was accordingly ordered to be closed as from that evening. The Reception Room remained open on the Saturday, to enable officers and members to wind up their business.

It was arranged that scientific communications not actually delivered should be taken as read, so that it is hoped to publish some of these in subsequent issues of this report. The emergency arrangements as to grants of money for research committees should also be recorded here. Few of the sectional committees had made their recommendations concerning grants; the Committee of Recommendations did not meet, and the General Committee

empowered the General Officers, after consultation with appropriate Sectional Officers, to make grants to research committees, subject to reference to the Council if in session. An inquiry has since been instituted as to how far individual research committees expect to be in a position to carry on their work in the immediate future.

The General Committee, otherwise, discharged their usual functions so far as it was possible to do so. They accepted, with acclamation, the Council's nomination of Sir Richard Gregory, Bt., F.R.S., as President of the Association for the year 1940. They reappointed the General Officers, and appointed the Council, in accordance with the list printed elsewhere in this issue. They were reminded that invitations have been accepted for the Association to meet at Newcastle-upon-Tyne in 1940, at Belfast in 1941, at Birmingham in 1942 ; and they received, and accepted, an invitation for a meeting in Brighton in 1943. May it prove possible to answer all these friendly calls ! The General Committee addressed a loyal message to the King, Patron of the Association : this, and His Majesty's gracious answer, are quoted below. And lastly, with something deeper than the usual warmth, the Committee thanked the City and the University College of Dundee, and all in Dundee and the vicinity who had contributed to the success of the meeting.

MEMBERSHIP AT THE DUNDEE MEETING

The General Treasurer, at the Inaugural Meeting on August 30, announced the number of tickets issued down to that date as 3,090. Further issues on the two following days brought the final figure to 3,186. It is worthy of note as showing the enthusiasm with which Dundee entered into the preparations for the meeting, that in the 106 meetings of the Association held between 1831 and 1938, a total of three thousand members had been passed on only seven occasions, excluding as exceptional the Australian meeting (1914) and the Centenary in London (1931). The seven occasions referred to are these : Manchester (1861), 3,138 ; Newcastle-upon-Tyne (1863), 3,335 ; Manchester (1887), 3,838 ; Liverpool (1896), 3,181 ; Liverpool (1923), 3,296 ; Oxford (1926), 3,722 ; Glasgow (1928), 3,074. The average for ten years preceding the present year and excluding 1931 has been 2,410.

* * * * *

THE LOYAL MESSAGE AND THE KING'S REPLY

The following was the message sent to the King by the President on behalf of the Association on September 1 :

> The British Association, whose meeting in Dundee is unhappily shortened by the present anxieties, send humble and affectionate greetings to His Majesty their Patron, and assure him, were assurance necessary, of their continued devotion and loyalty.
>
> SEWARD, *President.*

The following reply was received :

> Please convey to all assembled the King's sincere thanks for their loyal assurances which His Majesty as Patron much appreciates.
>
> PRIVATE SECRETARY.

THE PRESIDENTIAL ADDRESS

THE WESTERN ISLES THROUGH THE MISTS OF AGES

BY

EMERITUS PROFESSOR SIR ALBERT C. SEWARD, Sc.D., D.Sc., LL.D., F.R.S.

INTRODUCTORY.

TWENTY-SEVEN years ago, when the British Association met for the second time in Dundee, Sir Edward Schafer chose as the subject of his presidential address, the Nature, Origin, and Maintenance of Life ; he discussed problems that will long continue to exercise the ingenuity and stimulate the imagination of biologists and chemists. A theme such as his is far beyond my reach. Seventy-two years ago the Association met for the first time in this city. The Duke of Buccleuch occupied the presidential chair, and the opening words of his address are applicable to one who now finds himself in this privileged position : the Duke said 'No man has a title to state that he is unworthy of the post he is called on to fill, whatever may be his private feelings as to his fitness for the post. To state that he is unworthy to be there placed is not only a disparagement to himself, but is no great compliment to those who thought him worthy of being so placed.'

This, in my opinion, is not an occasion on which it is desirable to follow the easier course and address oneself in technical language to fellow-workers in the pursuit of natural knowledge. The position which it is my great privilege to occupy affords a rare opportunity of talking to a large and, I venture to hope, a sympathetic audience including some at least who are repelled by the jargon of specialists. My intention is to speak in ordinary language on a subject of which I know enough to realise how little that knowledge is, and briefly to describe an example of the way in which, within one small patch of an illimitable field, a student asks questions of Nature and does his best to interpret the answers.

AN EXCURSION INTO THE PAST.

I invite my audience to accompany me on an excursion of a kind which has substantially contributed to the enjoyment and enrichment of my own life, an excursion into a world that knew not man, with the object of

deciphering from such records as we find in the rocks a few pages of the story-book of the earth. Each one of us can say with Shakespeare's soothsayer :

> ' In Nature's infinite book of secrecy
> A little I can read.'

As that great Scotsman, Hugh Miller, wrote nearly a century ago : ' We find the present incomplete without the past—the recent without the extinct.' To reinforce his own opinion he quoted Samuel Johnson : ' Whatever makes the past, the distant, or the future predominate over the present, advances us in the dignity of thinking beings.' We shall try to reconstruct a small part of an ancient land, a remnant of which is now called Scotland, and envisage a scene at a stage in the history of the earth separated from the present by at least sixty million years, a stretch of time difficult for us who have been called ' the afterthoughts of creation ' fully to appreciate. When we substitute geological standards for the modest time-scale of the human period and remember that the earliest chapters of the world's history are recorded in rocks at least two thousand million years old, sixty million years dwindle to comparative insignificance. All that it is possible to do is to lift a corner of the veil separating us from the world as it was and view through dimly illuminated vistas the forests and undergrowth on an ancient continent that is now represented by a few widely scattered, dismembered pieces.

The History of Plant Life.

The history of plant life in the sea and on land is a branch of natural knowledge not unworthy of consideration by us human beings who owe our existence to the vegetable kingdom. Green plants in one vital sense are our superiors : from air and water they build up the complex organic substances necessary to our life, a feat beyond man's power. As members of a subject race we should be interested in endeavouring to unravel the history of the plant kingdom—in trying to trace the origin and relations of the several classes and groups as defined by botanists. The documents that are the sources of the botanical historian are contained in the earth's crust : as a preliminary it is worth while to ask ourselves of what these documents consist ; how they came to be preserved in the rocks. In order to bring to life the past we must take the present for our guide : ' speak to the earth, and it shall teach thee.' There is no reason to think of Nature's methods as other than continuous. If we stand by the bank of a river flowing past tree-covered slopes we see on the sand and mud by the edge of the channel or floating on the stream leaves, twigs, and seeds that are random samples of vegetation scattered by wind or shed from overhanging boughs, debris swept along with off-scourings from the rocks to be carried eventually to a delta or an estuary where the water-borne material comes to rest. Beds of old sands and mud, with included fragments of contemporary trees and other plants, exposed on the faces of cliffs and ravines, are layers of sediment that have been raised to a higher level. In addition to leaves, twigs and other scraps easy to see on the split surface of sandstone or shale, sediments of former ages, especially such as are peaty, occasionally furnish another valuable source of information invisible

to the unaided eye. Minute grains of pollen may be carried by wind to places where conditions are favourable for their preservation : fortunately the grains, or at least most of them, are protected by highly resistant coats and retain almost for all time their characteristic form and surface-sculpturing. With hardly any exception it is possible for a specialist, by comparative microscopical examination of fresh material, to assign fossil pollen-grains to their generic and occasionally their specific position in the plant kingdom.

There is another natural agency to which students of extinct plants are not infrequently indebted : the formation of rocks by volcanic action. From time to time volcanoes that have long been dormant eject clouds of ash : these with streams of lava poured over the rim of a crater spread havoc among trees and shrubs that had colonised precarious sites during a peaceful interlude. Vulcanicity is not only destructive : paradoxical as it may seem, forces inimical to life have contributed to the reconstruction of life which they destroyed. Scotland is exceptionally rich in botanical treasures that are legacies from ages of fire, and indeed the fossil plants with which we are concerned this evening owe their preservation to volcanic forces.

The following botanical restrospect is based mainly on results obtained during the last two or three years, but not yet published, by the joint efforts of Mr. W. N. Edwards, Keeper of Geology in the British Museum, Dr. J. B. Simpson of the Geological Survey, and myself.

Reconstruction of a Forest Scene.

A. *The geological background :*

(i) *Prolonged and intermittent volcanic activity.*

In order to present in true perspective the scene which it is my aim to bring to life, it will be helpful to visualise the physical features in north-western Europe some thousands of years antecedent to the phase of geological history chosen for closer examination. The Chalk Downs of England and part of the cliffs on the Antrim coast of Ireland are made of upraised calcareous material that was once a soft white ooze on the floor of a clear sea, a sea which had swept slowly and irresistibly over an enormous stretch of land, embracing the greater part of England, northern Ireland and part of the region that is now western Scotland. With the uplifting of the chalky ooze from the ocean bed and the gradual recession of the waters a new land was born ; a new chapter was inaugurated in the history of the earth. Following the great upheaval, as a consequential phenomenon, subterranean forces that had long been quiescent gained the upper hand : floods of semi-molten rock from deeply hidden reservoirs surged as a fiery deluge over the chalk downs, and over other and older rocks, converting thousands of square miles into barren lava-fields, extending over an area, not less than 2,000 miles from south to north, which reached far beyond the Arctic Circle. This unprecedented manifestation of volcanic energy, by no means confined to Europe and the arctic regions, but recorded on an equally titanic scale in the peninsula of India and elsewhere, is one of the wonders of geology ; it is convincing evidence that the earth after the lapse of many hundred million years had not lost her youth ;

there was no sign of senescence. During the period we are considering most of Britain was land : we know that at a slightly later date a broad sea lay over the whole of what is now southern England. Travellers in the tube-railway in the London district may perhaps derive pleasure from the knowledge that they are being conveyed through a stiff clay upraised from the floor of that ancient sea. As an appropriate designation for the great northern land an American geologist suggested the name Thulean continent or province. (See map, p. 16.) In the early days of the period called by geologists the Tertiary era, the greater part of the Thulean province was covered with sheets of sombre-coloured lava in nearly horizontal layers, products of a series of outbursts from deep fissures rent in the earth's crust under the compelling strain of subterranean forces and from localised volcanic centres of eruption. The columnar basalts of the Giant's Causeway, the columns of the 'cathedral of the sea' at Fingal's Cave, the basalts of Mull, Skye, Canna, Eigg, and other Western Isles, weathered into step-like terraces, which form a characteristic feature of Hebridean cliffs, the flat-topped McLeod's Tables of Skye (1,600 ft.), precisely similar basaltic platforms on the hills of Disko island and the mainland of western and eastern Greenland—all these are parts of one stupendous whole, a plateau covering half a million square miles, that was once the Thulean continent. The widespread lava-flows represent one phase of volcanic activity in an age of exceptional unrest. Another phase is illustrated by more coarsely crystalline rocks such as those of the dark Cuillin hills of Skye : they were not poured out as lava-streams over the land, but were forced upwards as great dome-like masses from a deeply-seated subterranean source and, as their coarser texture proves, slowly cooled under the pressure of a thick superincumbent load : the comparatively large size of the crystals indicates gradual solidification from a molten mass. These two phases of prolonged rock-building help us to appreciate the immensity of geological time. Describing the lava-flows of Mull, Sir Archibald Geikie wrote : 'On Ben More we can walk over each bed of basalt from the sea-level to the mountain top, a height of 3,169 ft.' The basaltic lavas we see in the cliffs of Mull and many other islands are but a part of the original pile : those that remain furnish an impressive example of rock construction which must have extended over an enormous period of time. The second phase, on the other hand, is an equally impressive example of rock destruction as a measure of geological time. We see the jagged peaks of mountains rising to a height of 3,000 ft. above sea-level which, at no distant date as earth history is reckoned, were buried under a considerable thickness of younger rocks that have been utterly destroyed by the ceaseless operation of denuding agents.

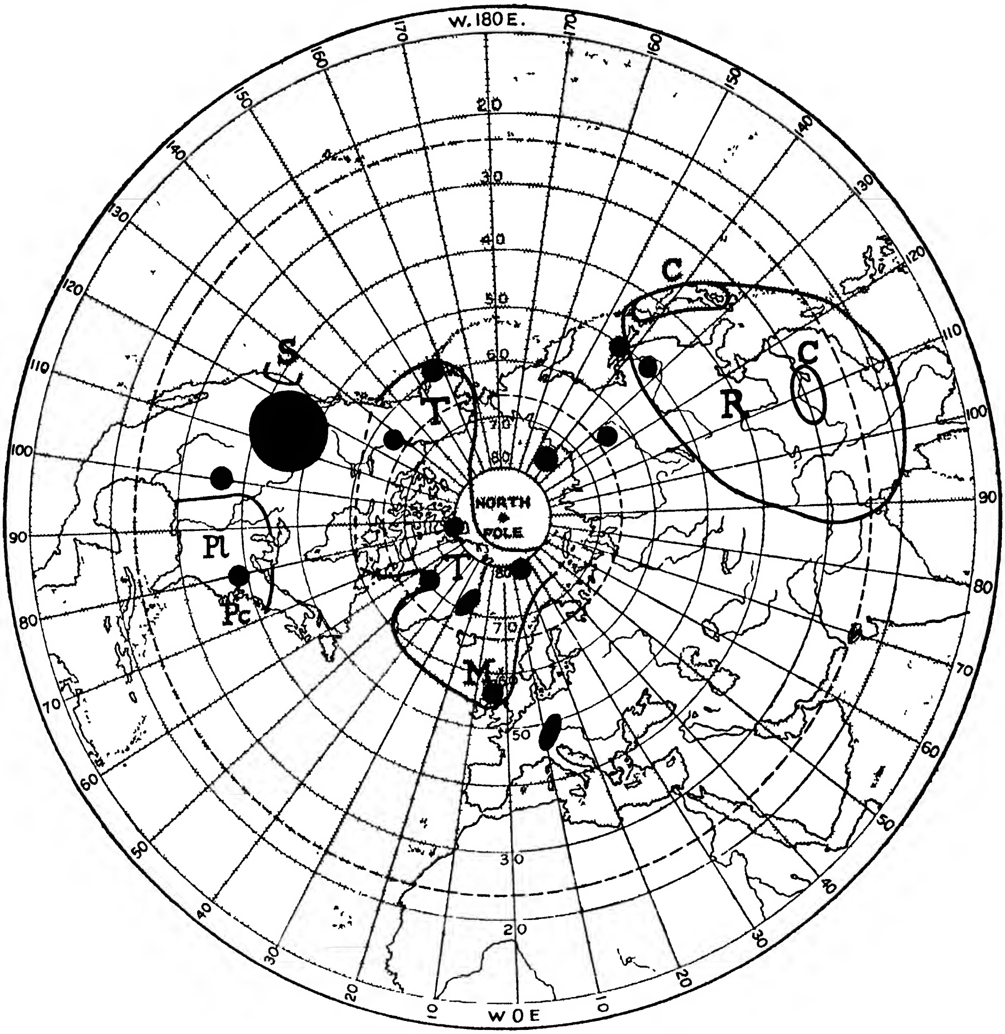
The world to our limited vision appears to be almost static ; the mountains we have been accustomed to think of as symbols of eternity, seen through geological spectacles, take their place as episodes in a series of events which have moulded the changing features of the earth's face. The rocky covering of the world viewed by geologists, 'foreshortened in the tract of time,' reveals itself as a dynamic, mobile crust responding from age to age to constructive and destructive forces which have operated since the earth's early youth following a still earlier stage when, in the imagery of the poet,

'This world was once a fluid haze of light.'

(ii) *Plant-bearing sediments indicative of quiescent intervals.*

So far the events chronicled in rocks of igneous origin have been spoken of as though there had been continuous outpourings of lava with occasional showers of ash and, in some districts, upwelling of molten material that remained hidden below the surface until in the course of time the covering rocks were removed by erosion. There is, however, clear proof that the extrusion of lava and other rocks was intermittent : intercalated among the lava-beds are layers of sedimentary material, hardened sand and mud, layers of coal, and beds of fine-grained limestone containing beautifully preserved leaves, a few fruits and other plant fragments, also rare examples of insect wings and shells. The richest plant-containing layers occur near the base of the pile of basaltic lavas on Ardtun Head, the low ' headland of the waves ' near the south-western corner of Mull, the island on which from his home on Iona- which has been aptly named ' the light of the western world '— Saint Columba must often have gazed. Trees, shrubs, and other plants were able to colonise portions of the lava-field during the long pauses between recurrent outbursts of volcanic fires.

The association of sedimentary material with the basalts at Ardtun Head was noticed by Abraham Mills as long ago as 1790 ; but it was not until the middle of the nineteenth century that Mr. McQuarrie of Bunessan discovered the fossil plants, which were very briefly described by Prof. Edward Forbes in an appendix to an important paper by the Duke of Argyll published by the Geological Society of London in 1851. The Duke spoke of the leaves as having been shed ' autumn after autumn into the smooth still waters of some shallow lake, on whose muddy bottom they were accumulated, one above the other, fully expanded and at perfect rest.' By far the richest collection of fossils was made by Mr. Starkie Gardner rather more than fifty years ago, and partially described by him in a paper read to the Geological Society of London in 1887. Descriptions of several fossil plants from the Mull beds have also been published by Dr. T. Johnson. The main collection is now in the British Museum. Additional specimens have been obtained by other collectors in more recent years. The work of deciphering the botanical records from Mull, Skye, and a few of the other islands is rendered mildly exciting by the danger of misinterpretation : fossil leaves, we are often reminded, are very uncertain guides—records left by Nature in a mischievous mood to mislead the unwary and over-confident student. Sir Joseph Hooker, in an address to the British Association at Norwich in 1868, spoke of Fossil Botany as ' this most unreliable of sciences ' ; but he added by way of consolation—' the science has of late made sure and steady progress, and developed really grand results.' One may cheerfully take the risk of being called an unscientific optimist by colleagues whose chief concern is with living plants. Botanists who confine their attention to recent plants have ample sources of information, not merely detached leaves but twigs bearing leaves, flowers, and fruits : it is natural, therefore, that they should tend to underestimate the value of leaf-form and venation, characters that are often the only criteria available to the palæobotanist.



MAP OF THE NORTHERN HEMISPHERE ILLUSTRATING SOME OF THE SUBJECTS DEALT WITH IN THE ADDRESS.

C, C. The present geographical distribution of *Cercidiphyllum*, a Japanese and Chinese tree.
Black patches mark localities and districts where fossil specimens of *Cercidiphyllum* have been found. Arctic and sub-arctic regions : Alaska, Mackenzie River, Grinnell Land and Ellesmere Land, West and East Greenland, Spitsbergen, New Siberian Islands, Lena River. Canada and the United States of America : several localities from British Columbia and California, and east of the Rocky Mountains in Montana, Wyoming, Oklahoma, etc. The oldest examples of *Cercidiphyllum* leaves are from early Cretaceous rocks in Maryland—the Potomac formation (Pc). Others are recorded from Europe—Mull, Switzerland, Bohemia, Silesia ; Eastern Asia ; Sakhalin Island and the Burcja River.

M. Mull and neighbouring islands.

Pl. The geographical distribution of the occidental plane.

R. Approximate boundary of the area within which are the present homes of the majority of trees and shrubs most closely related to extinct species of the Hebridean flora.

S. The present distribution of *Sequoia sempervirens* (Redwood) and *Sequoia gigantea* (Mammoth tree).

T. Hypothetical boundaries of the Thulean province.

B. *The ancient flora of the Inner Hebrides.*

What then is it possible to say about the ancient flora of the Inner Hebrides without transgressing the limits of probability? We know very little of the smaller and simpler plants which lived under the shade of the forest trees or clung to the surface of stems where they were washed by trickling rills of rain-water. The three smallest plants which have left recognisable fragments are a fungus and two liverworts or, as they are often called, hepatics, a group allied to the mosses but of simpler construction. The fungus was found by Mr. Edwards several years ago on some detached leaves of a conifer from the Mull plant-beds; the manner of its discovery illustrates an interesting technique often employed with success by students of fossil plants. In many instances leaves preserved on shale are covered with a very thin, black coaly film produced as the result of chemical change in the plant tissues after death. It is often possible, by detaching a piece of the film and treating it with certain clearing agents, to remove the carbonaceous matter and obtain a sample of the surface skin of the leaf that is brown in colour, transparent, and suitable for microscopical examination. After treatment the Mull leaves showed some minute dark spots on the surface film, and these on magnification were found to be circular discs made of rows of radially disposed cells. The discs were identified as organs of a fungus closely resembling reproductive structures of a living genus *Phragmothyrium*, a fungus now mainly tropical: the occurrence in Mull of a nearly allied form is, however, probably indicative of a moist rather than a tropical climate. One of the liverworts bears a close resemblance to a living species, *Pellia epiphylla*, which has a wide geographical distribution and is very common on damp earth in Britain; it has a flat green, forked body barely an inch in length. The other hepatic is a member of a different family, characterised by a slender thread-like stem bearing two rows of minute leaves; it bears a striking resemblance to some living species included in the order Jungermanniales. These two fragmentary remains of liverworts are worth mentioning because fossil examples of such plants are comparatively rare; also for another and a more important reason. A few years ago Prof. J. Walton of Glasgow published a description of some liverworts discovered for the first time in rocks containing remains of plants which grew in the forests of the Coal Age about 200 million years ago. The interesting fact is this: the Palaeozoic liverworts differ hardly at all in the construction of the delicate plant-body from the much later forms from the Thulean continent: both are essentially modern and yet both are surprisingly ancient. We do not know much about the history of these plants, but it is clear that some liverworts persisted through a succession of geological periods with practically no modification of their simple design.

The only fern so far discovered is very nearly related to the sensitive fern, *Onoclea sensibilis*, a familiar species in North America, ranging from Florida to Newfoundland and as far west as Saskatchewan; it occurs also in northern China, Manchuria, Japan, and Corea: it has what is called a discontinuous geographical distribution. *Onoclea*, no longer a native of Europe, is often cultivated. The fossil fronds from Mull, both sterile and fertile, differ hardly at all from those of the living fern. Records of the rocks show that *Onoclea* formerly grew in north-western Europe and in Greenland, regions where,

through the vicissitudes of climate, it long ago failed to survive. Evidence furnished by fossils and the facts of geological history affords a clue to the present discontinuous range: in all probability *Onoclea* originated on the Thulean continent, perhaps north of the Arctic Circle, whence it spread radially into America, Europe, and the Far East; in the European region it became extinct, sharing the fate of many other plants that were unable to survive the rigours of the Ice Age. Its territory was originally continuous; now it is restricted to North America and eastern Asia. Another member of the class to which the ferns belong is the familiar *Equisetum*, the horsetails: one species, closely comparable with the living *Equisetum limosum*—widely distributed in north temperate and arctic lands—has been found in the sediments of Ardtun Head. *Equisetum* may be described as an emblem of changelessness: nearly related forms grew in Palæozoic forests at least 150 or 200 million years ago: less closely related plants in the same forests—the calamites—were comparable in size with trees. The slender horsetails of the Coal Age and their much more robust and woody allies remind us that in the course of evolution some of Nature's early experiments survived unaffected by the production of new competitors, while others, less successful, left no direct descendants. As we follow the march of plant-life through the ages evidence of progress accompanied by retrogression becomes recurrently apparent: in the varying green mantle of the earth there can be traced threads running through the whole, changing very slightly as we follow them onwards and upwards, preserving all the time a remarkable uniformity in essential characters.

By far the greater number of the fossils from Ardtun are leaves of trees or shrubs, which belong to one or other of the two great classes of seed-bearing plants. In Gymnosperms, including conifers and some other less familiar plants, the seeds are naked. In members of the other class, the highest, the most various and most abundant in the vegetable kingdom, the seeds are more efficiently protected and are contained in a closed case; hence the name Angiosperms. Conifers played a prominent part in the Hebridean forests, but their representatives were not such as we find in modern Europe. A single and well-preserved seed attached to a relatively large wing affords evidence of the occurrence of a conifer allied to the Silver fir (*Abies pectinata*) and some other species commonly cultivated in Britain. Firs, using the term for trees belonging to the genus *Abies* and excluding the Spruce fir (*Picea*), now occur in Europe, northern Africa, northern Asia and America: there is no British species of *Abies*. The Mull seed, it is important to note, agrees most closely with seeds of firs now living in China and Japan. Among other conifers discovered in the plant-beds of Mull and Skye are *Cephalotaxus*, *Cryptomeria*, and *Sequoia*. Recent species of *Cephalotaxus* are comparatively small trees confined to the Far East; some kinds are cultivated in our gardens. The foliage of the Mull species bears a striking resemblance to that of *Cephalotaxus fortunei*, a small tree widely distributed in China. Another genus which we believe to have been a member of the Hebridean flora is *Cryptomeria*: the fossils from northern Ireland and the Isle of Skye include foliage shoots, cones, and pollen-grains. The solitary living species is the Japanese *Cryptomeria japonica*, which occurs also in China: this is the tree of the famous avenue of Nikko in Japan, a noble memorial of a peasant who was too poor in worldly goods to contribute the

usual building stone or a bronze lamp to the mortuary temple of an emperor, and instead offered to plant trees to protect visitors against the heat of the sun.

One of the most interesting of all living conifers is the genus *Sequoia*, of which there are two species confined within the narrow strip of hill ranges bordering Oregon and California on the Pacific coast—the Redwoods (*Sequoia sempervirens*) of the Coast Range, watered in the dry season by mists from the western ocean, and the Mammoth trees (*Sequoia gigantea*, often called *Wellingtonia*) of the Sierra Nevada. (See map, S, p. 16.) *Sequoia* is an impressive example of the light thrown by fossil plants on the past history and wanderings over broad regions of the earth's surface of trees that, without man's protection, would be in danger of extinction. In earlier periods *Sequoia* was almost cosmopolitan ; it ranged over wide spaces in the old and the new world and overstepped the limits of the northern hemisphere. Foliage shoots preserved in the sediments of Mull were in all probability borne by trees closely related to the living Redwoods, trees which are well worthy of inclusion among the wonders of the world ; they attain a height of over 300 ft. and the rings on cross-sections of giant trunks that have been felled bear witness to an age of 3,000 years and more. They were growing where they stand to-day 1,000 years before the Christian era. Trees next of kin to the Redwoods once lived within a short distance from the Polar Sea several hundred miles farther north than the present tree-limit. Another species of *Sequoia*, more nearly allied to the Mammoth tree, lingered on in Britain long after the disappearance of the Thulean forests : this we know from the discovery of fossil twigs and cones in the sediments of an old lake on the edge of Dartmoor in Devonshire. The two surviving species live in splendid isolation, dreaming of a greater glory that was theirs, their memories stored with secrets man can never know.

There was another naked-seeded tree in the forests into which we have intruded, a species of *Ginkgo*, the Maidenhair tree. The barbarous name *Ginkgo*, invented in 1712 by the German naturalist Kaempfer, is in the opinion of the Rev. Dr. Moule, formerly Professor of Chinese at Cambridge, a false transcription of Sankyo, which probably means hill-apricot. Leaves perfect in form and venation were found in the chalky sediment of a lake that filled a hollow in the Hebridean lava-field ; they differ from the foliage of the living tree only in a few minor features detected by the practised eyes of Dr. Florin of Stockholm in the microscopical structure of the superficial cells. Dr. Simpson discovered *Ginkgo* pollen-grains at another locality. The story of the Maidenhair tree has recently been told (*Science Progress*, January 1938), and the temptation to linger over it this evening must be resisted. *Ginkgo* of all trees furnishes the most thrilling example of a link with the past ; its history compiled from fossils of many geological ages and in many parts of the world is an enthralling romance. This is but one of many histories recorded in Nature's story-book which makes us share the thought of Edward Fitzgerald : 'Yes, as I often think, it is not the poetical imagination but bare science that every day more and more unrolls a greater epic than the Iliad.' It would be rash definitely to assert that the Maidenhair tree still exists under strictly natural conditions as a wild tree of the forest. Botanists who have searched for it in China, the country believed to be its last home, failed to discover convincing

evidence of the occurrence of specimens which could not be ascribed to man's agency. On the other hand, a few years ago a Chinese botanist expressed the opinion that *Ginkgo* still grows wild in the province of Chekiang in eastern China. The oldest living examples occur in China and Japan, often in places where, as is fitting, they are venerated as trees endowed with healing properties. The history of *Ginkgo* has been traced to periods antedating by millions of years the Thulean forests : we do not know of what sort its progenitors were ; but we know that it is a survival from an age too remote for us to measure in terms which we can fully appreciate. We also know that *Ginkgo*, now a lonely relic in the present world, is a primitive and isolated type, the sole representative of a large family, including many different members, all of which save the Maidenhair tree long ago fell by the way in the struggle for existence. When the tree lived in the Hebridean forests it was common in other parts of the Thulean continent from northern Canada to Greenland and Spitsbergen, in North America, Europe, and Asia. It was as widely distributed geographically as oaks, pines, and firs in the modern world. The history of *Ginkgo* is a record of endurance, of persistence with apparently little change in an unstable world. When we recall the amazing life-story of the tree and its forbears the autumnal colour acquires a deeper significance : we see in the pale yellow of the leaves a reflection of the golden age of a family that left a precious legacy. Would that the Maidenhair tree were endowed with the oracular power of the oaks of Dodona and, in the trembling accents of its fluttering leaves, could tell us not of the future but of the varying fortunes of the family as age succeeded age.

The *Ginkgo* of Mull was not the last of its race in Europe : well-preserved remains have been found in younger rocks in France and Germany proving that it survived in the western world, though probably only in a few places, to an age preceding by a comparatively short period the invasion of temperate Europe and North America by arctic ice-sheets and glaciers, which had a far-reaching effect upon the vegetation in the western world.

Leaving the naked-seeded plants, we pass to the flowering plants or Angiosperms. This class is more recent in origin than the Gymnosperms, at least so it would seem, and as in present-day floras so also in the Thulean forests, flowering plants contributed the greatest number of genera and species. We shall take first a few trees and shrubs which have descendants still living in Europe, and afterwards mention others that have no near relations in European floras. There were, we think, three or four kinds of oak, all different from those now living in Europe and America. The largest leaves from Mull assigned to the genus *Quercus* are oval, with a broadly rounded base and relatively small teeth ; they resemble the foliage of a few Indian species, but the oak with leaves most closely resembling the fossil form is *Quercus serrata*, a native of China, the rain-forests of Assam, Japan, Corea, and the Himalayas. A second species from Mull is closely comparable with other Indian and Far Eastern oaks ; and a third form of leaf is very similar in shape and venation to a species that now has its home in China, Assam, and the island of Formosa. It is noteworthy that none of the oaks of the Thulean forests conformed in pattern of the foliage to our familiar British trees.

One of the most conspicuous trees in the Hebridean woodland was a plane (*Platanus*) with large handsome leaves almost, but not quite, identical with those of the existing occidental plane of North America. The fossil evidence

in this instance is supplied by male flowers and fruit-balls as well as leaves. As in all living planes the expanded base of the leaf-stalk enclosed and protected a bud. There is, however, one interesting feature in which the leaves of the Mull tree differ from those of any living plane : there were two fairly large leaflets attached to the long leaf-stalk between the main part of the leaf and the base of the stalk. The significance of this peculiarity need not be discussed ; it is one of those botanical problems of academic interest which excite the specialist. A more important fact for us is that plane trees in the period we are considering occupied a territory which extended very much farther north than the present area of distribution. Remains of plane trees have been found as far north as Spitsbergen in rocks approximately equivalent in age to those of Mull. There are in the world to-day six or possibly eight different kinds of plane : the oriental plane (*Platanus orientalis*), the only species native in Europe, is one of the noblest living trees ; it recalls the groves of the Academy in the golden age of Greece. One of the oldest specimens is the venerable stump bearing enormous arms in the market place on the island of Cos where, legend would have us believe, Hippocrates, more than two thousand years ago, gave advice to his patients under the shade of the youthful tree. The oriental plane extends from Greece and the Aegean islands eastward to Asia Minor and the Caspian Sea ; it is sometimes said to be wild in Persia and northern India, but more probably this eastward spread should be attributed to man. The most widely distributed species in the New World is *Platanus occidentalis*, growing usually in river valleys from Lake Ontario to Florida and west to Texas and Nebraska (see map, Pl, p. 16). On the western side of North America there are other species, in Mexico and along the Coast Range hills of California. The most familiar cultivated species in Britain is *Platanus acerifolia*, the so-called London plane : this favourite urban tree is regarded by some botanists as a hybrid between the oriental and the occidental plane ; the time and place of its origin are not known with any certainty. The geological record of *Platanus* affords a striking example of contrasts between past and present areas of distribution. Some of the oldest known fossil leaves and fruits are from early Cretaceous beds in Greenland, at least 300 miles north of the Arctic Circle. The occurrence of these remains in sediments that were deposited in a remote northern estuary before the chalk of the British Isles had been upraised from the sea-floor affords definite proof that plane trees lived in arctic forests millions of years before they spread to the southern part of the Thulean continent. The birthplace of *Platanus* may have been in the far north, whence in course of time it spread to Iceland and Spitsbergen, from arctic to temperate North America and Europe, and wandered as far east as Sakhalin Island on the eastern confines of Asia.

One of the comparatively few trees in the Hebridean forests related to recent British species was a *Corylus* with leaves similar to those of our hazel but still more like the foliage of species now living in India and the Far East. Hazels were associated with planes not only in the ancient flora of Mull but in circumpolar forests from which they travelled, in response to the urge of climatic change, to fresh and more genial homes farther south. Another tree in the Thulean forests was a cornel, a species of the genus *Cornus*, which has a far-flung distribution, in arctic and sub-arctic countries, in North America, Europe, and Asia. While fully conscious of the danger of placing excessive

trust in leaves as evidence of affinity, we believe that a Chinese cornel (*Cornus chinensis*) agrees most closely in foliage with the Mull species. The cornels are members of an old stock represented in northern forests as long ago as the Cretaceous period.

Among the larger fossils from Ardtun Head are a few almost perfectly preserved leaves of a vine, which we believe to be specifically identical with specimens previously discovered in Alaskan rocks of approximately the same geological age as those associated with the lava-flows of Mull. Similar leaves have been described from Greenland, Iceland, Spitsbergen and more southern localities in America and Europe. Vines were widely distributed even as far back as the Cretaceous period : there is now only one European species, the wine-producing *Vitis vinifera* ; but its leaves are unlike the fossils from Ardtun. The striking contrast between the present distribution of the vine in Europe and its former, much more extended distribution which included arctic and north temperate regions, raises the difficult problem of changes in climate from one age to another. Vine scrolls are a fairly common ornament on early Northumbrian Anglo-Saxon crosses, a motif adopted in still earlier ages by Greek and Roman sculptors, which, after the lapse of centuries, reached the highest expression of naturalistic treatment in England in the last two decades of the thirteenth century. Millions of years before vine leaves and fruit were fashioned in stone, one kind lived in pre-human days on the Thulean continent ; and it is noteworthy that its nearest counterpart in the modern world occurs in the Far East.

We turn now to trees and shrubs belonging to genera which are no longer living in Europe. The first tree to be considered furnishes a striking contrast, in the narrow limits of its present geographical area, to the widely spread cornels and oaks. *Cercidiphyllum* is now confined to Japan and mountain valleys in some parts of China (see map, C, p. 16). The name *Cercidiphyllum* was chosen because of a superficial resemblance of the leaves to those of the Judas tree, *Cercis siliquastrum* : only a single species, with a few varieties, has survived, *Cercidiphyllum japonicum*, familiar to many tree lovers who cultivate it for the sake of the exceptionally beautiful gold, pink, and red parti-coloured autumnal foliage. In common with some other trees of ancient lineage, *Cercidiphyllum* lacks any near relations in the present age ; it is one of a select company of Nature's anachronisms. Like the Maidenhair tree, it is an aberrant type, a relic living within a comparatively small area in the Far East : formerly it was one of the most widely distributed forest trees on both sides of the Atlantic ocean. Several beautifully preserved leaves have been found in the plant-beds of Ardtun Head, leaves and occasionally fruits of *Cercidiphyllum* have been found in Grinnell Land and Ellesmere Land on the north-eastern corner of the Canadian Archipelago, in Alaska and at several localities on the Pacific and Atlantic coasts of North America, in Greenland, Iceland, and Spitsbergen, as well as in Switzerland and other parts of Europe (see map, p. 16). Leaves, superficially at least indistinguishable from those of the existing species, are recorded from sedimentary beds in the valley of the Potomac River in Maryland assigned to the early days of the Cretaceous period when flowering plants were comparatively few in number and had not yet come into their own as the dominant class in the plant kingdom. When we remember the remote antiquity of *Cercidiphyllum* and its wanderings over the earth's surface during

the passing of millennia, the autumnal glory of its foliage is enhanced a hundredfold and acquires a symbolic meaning.

The plant-beds on the headland of Ardtun have yielded very few recognisable fruits and seeds. Among the rare examples of fruits are some, about half an inch long, consisting of a slightly elongated seed-vessel surmounted usually by five leaflets, the enlarged and persistent covering of the young flowers, which served as efficient aids to dispersal by wind. The fossil winged fruits and associated leaves present a remarkably close resemblance to those of some living species of *Abelia*, a genus named after Mr. Clarke Abel, who discovered the shrub in China about one hundred and twenty years ago. *Abelia* is a member of the honeysuckle family (*Caprifoliaceae*) : most of the existing species have their home in Central China and are cultivated as flowering shrubs in European gardens. There are a few species in Japan, the Himalayas, and Mexico. Fruits of a Chinese *Abelia* agree most closely with the fossil specimens. Similar though not specifically identical fruits were discovered thirteen years ago by Mrs. Clement Reid and Miss Chandler in a collection of fossil plants from Bembridge in the Isle of Wight. The Bembridge flora is younger geologically than the flora of Mull and indicates a warmer climate. Other examples were recorded long ago from south-eastern France. It is therefore clear that shrubs next of kin to Abelias now living in China were once native in western and northern Europe. The introduction to British and continental gardens in our time of *Abelia*, *Cercidiphyllum*, and other trees and flowering shrubs may be described as the reinstatement, through man's desire for horticultural novelties, of plants that had long been exiles from western woodlands where as natives they were never seen by human eyes.

So far attention has been confined to a selection of plants identified from leaves and a few fruits. If time permitted, the list could be substantially enlarged by inclusion of the interesting results of Dr. Simpson's intensive study of pollen-grains, which he found by microscopical examination of broken-up pieces of lignite and coal, associated with sandy beds in Mull and on the adjacent peninsula of Morven. The pollen-bearing layers of rock are below the basaltic lavas and therefore slightly older than the leaf-beds of Ardtun Head. Dr. Simpson discovered several conifers and flowering plants confirmatory of identifications based on leaves ; he also made many additions to the list compiled from leaves, fruits, and seeds. Three of his discoveries are selected for brief reference. He found pollen-grains of two kinds of alder (*Alnus*) : the pollen of alders has a very characteristic structure and can easily be recognised. The occurrence of alders in the Hebridean flora supplies one of the few links between the extinct and the present European vegetation. The second genus chosen from Dr. Simpson's list is *Magnolia* : it is now represented by many species, both trees and shrubs, and is widely distributed on two sides of the Pacific ocean : in Asia along the Himalayas and in parts of Tibet, over a large area in China, Japan and Corea, the Malay Archipelago, and Indo-China; in America from southern Ontario as far south as Central America and Cuba. It was shown many years ago that *Magnolia* formerly lived in Europe and flourished as far north as lat. 70° N. in Greenland ; we now know that it played a part in the adornment of the Thulean forests.

Finally a few words on the discovery of pollen-grains believed to belong to a species of *Nelumbium* : this genus is one of the most attractive water plants,

a plant held sacred in ancient Egypt and venerated in the Far East. One of the living species is the sacred lotus, native in China and Japan and established as far west as the Caspian Sea ; the other species has an extended range in North America, spreading as far south as the West Indies and Brazil. *Nelumbium* no longer grows in the Nile : long years ago it had a wide distribution in Europe, both in the Cretaceous period and in later ages. Looking backwards we see its great circular leaves spread over the still waters of a Thulean lake.

It is important to note that Dr. Simpson's comparative investigation of fossil and recent pollen shows a preponderance of eastern Asiatic species in the Hebridean flora.

Fancy with Fact.

We have attempted to re-create a scene in the past, and it is natural to ask—how does our reconstruction compare with reality? As it is impossible to satisfy curiosity by an actual flight to the Thulean continent, we can at least imagine ourselves miraculously transported to a destination where the past has become the present. At a very early stage of the backward journey we should see the greater part of the land being gradually obliterated by a covering of snow and ice ; glacial conditions would be succeeded by a climate becoming more and more genial. Human beings would be missed before one-fiftieth of the flight had been completed. At last, after observing the moving panorama of land and sea, fluctuations in climate and changes in the character of the vegetation, let us imagine ourselves at the journey's end. Combining fact with fancy, we find ourselves, where in day-dreams we have often been, among the plants on the lava plateau. Thanks to the artistic co-operation of Mrs. Gwendy Caröe, it has been possible to give substance to our mental picture based on geological and botanical facts. It requires a special effort for us, who think of ourselves as overlords in Nature's realm, to visualise a world in which man has no place. Alone in a world which for millions of years to come would be uninhabited by the human race, we could hardly fail to look upon the beauty of Nature's pageantry with a strange and more penetrating vision :

> ' Beauty, the eternal Spouse of the Wisdom of God
> and Angel of his Presence thru' all creation.'

We should realise as never before man's insignificance : on the other hand, our estimate of spiritual values would be raised to a higher level and we should experience a deeper sense of union with the infinite. Our tendency is to think of the past, as we think of the present—in relation to man ; we forget his very recent participation as an actor in life's drama. As we look at Nature as into a mirror our own image obtrudes itself into the foreground. Had man been a dweller on the Thulean continent he would have seen, as we see, the sun by day setting in motion the living machinery of trees and herbs ; the splendour of the evening sky ; he would hear the wind in the trees, the music of running water and the songs of birds. The beauty of Nature is eternal. To the east and north beyond the lava-fields the Caledonian mountain ranges would be seen rising to greater heights than any of their peaks reach to-day ;

they were still to be exposed for millions of years to the destructive operation of Nature's sculpturing tools. Making a fresh demand upon our imagination, let us take a longer view over the curve of the earth towards the heart of Europe and far to the east to northern India. We should look in vain for the Pyrenees, the Alps, the Carpathians, and the Himalayas : these and other mountain ranges had not yet been lifted up ; the time of their birth was not far off. We should see in their place a broad belt of water stretching from the Atlantic to the Indian ocean, linking West with East. On the bed of this ancient sea—the Tethys Sea of geologists—sediments had long been accumulating, and these, with other rocks of igneous origin, would be involved at no distant date in a complete transformation of the earth's features and the crumpling of the crust into the ' everlasting hills.'

Returning to the Thulean continent at a place near the present geographical position of the Inner Hebrides, let us take a survey of the vegetation. We should be impressed by its luxuriance : at first sight the general aspect would seem familiar, but on closer examination of the trees and shrubs we should find only a few recalling modern European species ; many would remind us of exotic plants of eastern origin. Despite the immensity of the time interval separating us from the world we had left, we should not be aware of any such marked contrast in the general character of the vegetation as we might have expected. The plants had already put on their familiar dress and would seem to us surprisingly modern. But—and this would be the deepest impression—we should feel that we were among trees and shrubs that were reminiscent of remote eastern forests. We should be conscious of the dynamic character of the plant-world ; we should be driven to the conclusion that the forests were mainly composed of wanderers resting for a time in a temporary home whence, as conditions changed, they would pass to other stages in the long journey to their present refuges in Asia.

Evolution.

There remains another question which is always asked by those who attempt to reconstruct the vegetation of past ages : what contributions do the records of plant-life make towards a better understanding of evolution ? The riddle of evolution remains a challenge and, as knowledge increases, we make fresh guesses: As a Cambridge friend writes in a recent volume of *Provocative Verse* :

' That life evolves was guessed of yore,
Darwinians prove it true ;
Of how and why we know but little more
Than old Lucretius knew.'

The little more we know urges us to continue in hopeful expectancy the long and endless prying into Nature's methods. What then do we learn from the ancient flora of the Western Isles ? The facts do not substantially help us to trace the unfolding of life in the long interval separating the older part of the Tertiary era from the present time. There is little difference between the past and the present vegetation of the world as a whole in the nature of trees, shrubs, and ferns : our knowledge of the earlier history of herbaceous plants

is very meagre. The fossil flora of Mull represents an early phase of what may be called the modern type of vegetation, which overspread the world in the later stages of the Cretaceous period and has persisted with few major modifications until now. Evolution seems to have been characterised by bursts of production when new and successful types exercised a transforming influence ; and these periods of exceptional creative activity were separated by periods of relative stability. The early Tertiary floras belong to a stage when a new order had become well established and an older order had passed its prime. The one great difference that emerges from comparison of the Mull flora and the existing European floras is not a difference in the components of the world forests, but a contrast in the geographical positions occupied by the various genera in the northern hemisphere : for the most part a western home has been exchanged for a home in the Far East.

Drifting Continents.

If we followed the vegetation on the southern part of the Thulean land farther to the north, we should be impressed by its apparent indifference to changing physical conditions as we travelled beyond the Arctic Circle ; we should fail to notice any zonal distinguishing characters in the floras such as in our day reflect the passage from temperate to arctic regions. The evidence of fossil plants forces us to the conclusion that the vegetation on the Thulean continent, its northern boundary within a short distance of the polar sea, its southern border on the latitude of northern Ireland and western Scotland, was astonishingly uniform. How, we ask, can we explain this surprising and well-attested fact ? There must, it is generally agreed, always have been climatic belts ; high arctic and much lower temperate regions cannot have supported closely comparable floras possessing several species in common. Some of us are convinced that changes in geography from one period to another, land connections where there are now arms of the sea, interference with paths of ocean currents and consequential changes in temperature are inadequate as explanatory causes. What then remains ? Were it possible for us to make a survey of the Thulean continent as it was, we might find that the geographical relation of the northern part of the forest-clad land to the North Pole was by no means the same as it is now. It is difficult, it is probably impossible, to explain the facts without calling to our aid the hypothesis of drifting continents usually associated with the late Prof. Wegener and recently discussed in an able book by Prof. Du Toit of South Africa. This is a controversial subject beyond the scope of my address : I can do little more than reaffirm adherence to the view that plant records from rocks of many ages raise problems which seem to be insoluble unless we postulate movement and sliding of the earth's crust. As icebergs are slowly drifted by ocean currents, as masses of cumulus clouds rapidly changing shape pass across a blue sky ; so, the rate of travel enormously reduced, large slabs of the outermost rocky shell of the world may have shifted their position in the course of geological time. It must, however, be admitted that as yet refined methods of measurement have not furnished any evidence of crustal movement. Dr. Nörlund of Copenhagen has stated that longitudinal determinations, carried out by the Danish Geodetic Institute in 1927 and 1936 with a modern

transit instrument, both times on the same pillar at a locality on the west coast of Greenland, gave practically the same result. In his presidential address at the Norwich Meeting of the Association in 1935 Prof. W. W. Watts made an interesting and judicial reference to the Wegener hypothesis: he spoke of it as having been hailed by many classes of investigators as almost a panacea, and quoted one of several critics who called it a beautiful dream, the dream of a great poet.

Proof or disproof of the Wegener hypothesis will be forthcoming in the more distant future when the precision of modern methods of measurement has been available long enough to provide trustworthy data. Meanwhile we must be content to wait in sanguine expectation that an interpretation of the overwhelming evidence furnished by fossil plants will be provided by research workers in the geophysical field.

One of the most impressive examples of the bearing of fossil plants upon the fascinating problem of climatic conditions in the past has been furnished by Prof. Harris of Reading. The facts are briefly these: several years ago Prof. Nathorst of Stockholm described a large collection of fossil plants from rocks in Scania, the southernmost province of Sweden, demonstrating the existence of a flora many million years older than the one we have been considering. It was a very rich flora composed of numerous ferns, conifers, and other plants; it probably lacked flowering plants. More recently Prof. Harris made a still larger collection of fossils during a long visit to eastern Greenland in the ice-bound district of Scoresby Sound where, under extreme arctic conditions, only a few stunted plants are able to exist. Nothing could be more striking than the present contrast between the floras of eastern Greenland and southern Sweden. The arctic fossil plants of the same age as those from Scania demonstrate the former existence of a flora even richer than that from southern Sweden: comparison of the two floras affords no indication of any difference in the size of individual plants and no difference in the vegetation as a whole. A luxuriant and uniform vegetation occupied an area stretching from central Germany to southern Sweden and a thousand miles farther north beyond latitude 70° N. The fossils preserved in rocks at localities within this far-flung geographical area from south to north give no indication of any such change in the plant communities as we should expect and as we find when we contrast arctic and temperate floras in the present world. This uniformity, I venture to think, is inexplicable unless we assume a very considerable movement and reshuffling of the earth's crust. The geological historian needs the co-operation of astronomers and physicists in his endeavour to reconstruct the world at the successive stages of its development; he looks to them to prevent him from making assumptions inconsistent with conclusions reached by workers in other fields. On the other hand, geologists and palæontologists contribute facts that are incontrovertible however much they seem to be in opposition to the views of students whose primary interest is in geophysical problems.

Neglect of Earth History in Education.

There are still some people who ask, what is the use of the kind of information given in this address? My reply is that knowledge gained from a

first-hand study of nature, both animate and inanimate, has a value beyond price. Enjoyment of the romance of creation as recorded in the life of the past and of the present is within the reach of all who have the desire to read the open pages of Nature's book. In the rocks we find the soul of history : the whole world throbs with life, and the joy of it all is ours to share :

> ' I said it in the meadow path,
> I said it on the mountain stairs—
> The best things any mortal hath
> Are those which every mortal shares.'

This evening we have caught through the mists a glimpse of a scene on earth's stage separated from the present by a small fraction of time in relation to the whole span of geological history. The Thulean forests which we have visited included trees, shrubs, and other plants of surprisingly modern aspect, though it is not to be supposed that they were absolutely identical specifically with their living descendants ; from the material available it is impossible to define or assess the difference. What we have seen throws little light on the evolution of the plant-world ; it is equally true that the main conclusion forced upon us by our retrospect cannot fail to convince us that it is impossible to understand the present distribution of plants over the earth's surface unless we extend our survey into the past. Darwin spoke of geographical distribution as a noble science, ' almost the keystone of the laws of creation.' The living world cannot be fully appreciated as an expression of creative energy unless we free ourselves from the cramping influence of the environment in which we live.

As a botanist whose first love was geology, may I make a plea for wider recognition of physical geography and geology as branches of knowledge possessing an inestimable value as a means of bringing young people into close companionship with Nature and as a source of refreshment, a stimulus, and an inspiration. Most of us would probably agree with the spirit of a remark made a good many years ago by the late A. C. Benson : ' I find it hard to resist the conviction that, from the educational point of view, stimulus is more important than exactness.' Arguments in favour of introducing geology into schools were put forward in a Report on Scientific Education presented at the Dundee Meeting seventy-two years ago, and in 1936 and 1937 the Association published two Reports on the same subject. Let me add another argument of no little value : Hugh Miller wrote in a letter to a friend, ' geology is, I find, a science in which the best authorities are sometimes content to unlearn a good deal.' That is worth much : geology helps us to cultivate the not too common virtue of admitting that it is possible to make a mistake. In conclusion, I cannot do better than quote with wholehearted agreement words spoken by Sir William Bragg in his presidential address to this Association eleven years ago : ' Some speak of modern science as tending to destroy reverence and faith. I do not know how that can be said of the student who stands daily in the presence of what seems to him to be infinite.' These words apply with equal force to searchers after truth whose main interest is in the living world no less than to those whose objective is the elucidation of the structure of matter that is called by contrast dead and yet vibrates with life. The earth was once lifeless : when and how living protoplasm had its birth we do not

know, nor do we know whereupon were the foundations of the earth laid. We can only echo in our hearts the voice out of the whirlwind :

> ' Whereupon were the foundations thereof fastened ?
> Or who laid the corner stone thereof ;
> When the morning stars sang together,
> And all the sons of God shouted for joy ? '

PERSPECTIVES IN EVOLUTION

ADDRESS TO SECTION D.—ZOOLOGY

By Prof. JAMES RITCHIE, M.A., D.Sc.
PRESIDENT OF THE SECTION.

' All useless science is an empty boast,' Shakespeare is alleged to have said, but he lived before that pernicious cleavage had been made between pure science and economic science, which suggests, as Hinton once said, that the latter is a gold-digger while the former excavates only knowledge. And while we are strongly in favour of those lines of scientific endeavour which make their first purpose an attack upon the evils that man and his possessions fall heir to in the course of nature, and which aim at easing the human struggle for existence, there are questions of no immediate practical moment to which the inquiring spirit of humanity demands an answer. I do not think Shakespeare would have called these recurrent problems ' useless science,' for the mind of man requires satisfaction as well as his material need.

It is characteristic of the modern evolution of scientific method that as the zoologist becomes more and more engrossed in a particular problem within the restricted field in which he specialises, his opportunities recede of gauging the effect of discoveries in other fields upon the general problems of life. Even if he desires to keep in touch with such inquiries, whom is he to follow ? Juvenal declared that ' Nature never says one thing and Science another,' and while that is true of Science in the abstract, it can scarcely be true of the purveyors of exact knowledge so-called, the scientists, for they speak with many and often discordant tongues.

There is another reason which suggests that a re-statement of some of the great problems may be appropriate on this occasion. Since the British Association last met in Dundee, in 1912, and Sir Peter Chalmers Mitchell addressed this Section upon the need for furthering the protection of animals whose existence was threatened by the advance of civilisation, great progress has been made in many directions. Much has been done, for example, for the cause so competently advocated by Sir Peter Mitchell ; but in no direction has there been more striking endeavour than in the testing of old and once widely accepted theories by the touchstone of detailed analysis and experiment.

That is a distinctive feature of post-War zoology, and its milestone was erected by Alfred J. Lotka in 1925. It has had a salutary effect upon theorising, for 'Experience is the greatest baffler of speculation,' but if speculation gains in precision through running this new gauntlet, it must not be forgotten that experiment also gains from the association : 'Knowledge directeth practice and practice increaseth knowledge.'

So, since I think that truth may lie between analysis of long-range views and synthesis of detailed discoveries, I take this opportunity of laying before you some ideas concerning life and evolution.

The Secret of Life.

There was a Scottish politician and philosopher, a former Duke of Argyll, who, amongst many sayings that are forgotten, took pleasure in reminding the world that 'Science has cast no light on the ultimate nature of life.' He stood for the rather facile vitalism which loves a mystery and regards the probings of science as bringing knowledge only with the accompaniment of disillusionment. In the opposite camp is the mechanist, in whose view the processes of life are to be explained solely and completely by the concepts of chemistry and physics. The two aspects, the mechanistic and the vitalistic views, have been canvassed so thoroughly that it would be profitless to trace the controversy again, if indeed the controversy has any real antithesis and does not represent simply two facets of one common truth. But it is legitimate to ask what recent years have contributed towards the solving of the secret of life.

The outstanding fact which strikes the observer is that the extreme positions, physical and biological, have become untenable, and that concessions are being made by both sides. The vitalist's vitality is being whittled down, animation is being put into the mechanist's machine. Sir James Jeans (1933) from the physicist's point of view has stated that living things in some way possess the power of evading the established physical order of disorganisation, and in so doing he has conceded more than most biologists demand. When, in his plea at the Cambridge meeting of this Association, in 1938, for the inclusion of probability in the scheme of physical conceptions, Dr. C. G. Darwin stated that the trouble about forecasting the future from our knowledge of the present was the impossibility of knowing the present, he was formulating precisely that difficulty of knowing the conditions of life activity which besets the biological experimenter in endeavouring to interpret life axiomatically, a difficulty which appears to be insurmountable. A common ground, even if it be largely a common ground of uncertainty and cautiousness, is being approached by the schools of physics and biology.

Broadly it may be said that the efforts of recent years have done much to reduce the mystery of life. An elusive quality remains, but the elusive quality is retreating within its shell, and its shell becomes smaller and smaller, just as the corresponding physical mystery has been driven from stronghold to diminishing stronghold, from molecule to atom, from atom to proton and electron with the irreducible quantum of activity. Such advances as have been made in the interpretation of life have been due to the application of physical and chemical methods and concepts.

There have been theoretical interpretations, working hypotheses founded

rather on analogy than deduced from direct observation, like the oscillatory theory of Lakhovsky (1929), who regards the cell as an electromagnetic resonator, active in absorbing and emitting radiations of very high frequency. Life, in his view, is the dynamic equilibrium between such cells, the harmony of innumerable radiations reacting upon each other. Or the vortex theory of Lartigue (1929) who, endeavouring to extend to the domain of life the laws of eddies, comes to the conclusion that the living organism is not an ordinary thermal machine, since it works at a temperature practically constant, nor an ordinary electrical machine, since it works at a practically constant potential, nor an ordinary chemical machine, since there is no sufficient explanation of the activity of its chemical processes taking place almost at neutrality. Instead he looks upon the living cell as a thermo-electrical unit based upon an etherial vortex, and the appearance of life upon the earth as the appearance of such a vortex activated by a triple movement of centripetal precipitation, of centrifugal diffusion, and of ellipsoidal or cylindrical rotation, and sufficiently persistent to construct a body by sweeping along matter in its train and thereafter to engender other vortices specifically like itself.

These are tenuous speculations at best. It is to the lasting credit of the Department of Zoology in this University College of Dundee that it gave to the world a reasoned dynamical interpretation of organisms which, working on solid ground, revealed the physical basis of much that had been regarded as manifestations of the peculiar properties of life. His presidential address to our Section of the British Association at Portsmouth in 1911 showed that Sir D'Arcy Thompson had already been turning over in his mind the adequacy of the forces of surface-tension, elasticity and pressure to explain a multitude of the phenomena illustrated in the appearances of living things ; but the publication of *Growth and Form* in 1917 exposed, with a wealth of detail that set the subject in a new light, the far-reaching influences of physical forces on the growth and ultimate conformation of organisms and the parts of organisms.

While the structures, the ' things seen ' in the architecture of animate nature, have been yielding their secrets to such physical analysis, the activities of living stuff, far less easy to comprehend, and yet more intimately part of life than the material plasms through which they are expressed, have also been giving way to the skilled attacks of the physicist and chemist. Here investigation has naturally been concentrated upon the unit of organisation, the cell, and it has shown that just as the cell-boundary is determined by physical forces, of surface tension, so activities of the living cell-membranes, which form its boundary, also fall into line, so far as analysis goes, with physico-chemical laws. Thus the living cell, of plant or animal, acts as an osmotic system, as de Vries showed long ago with the leaf cells of *Tradescantia* and as has been shown for many animal cells such as mammalian red blood-cells and leucocytes, spermatozoa, muscle cells of frogs and egg cells of echinoderms. Moreover the adjustment of forces within and without living cells has been found to be in accordance with the thermodynamical balance known as the ' Donnan equilibrium ' or ' membrane equilibrium,' which interprets the relationship between solvents separated by a membrane, on one side of which is a non-diffusible ion or molecule. (For a summary of the biological aspect, see Dixit, 1938.) Part of the activity of a cell, at any rate, is amenable to purely physico-chemical explanation.

Further understanding of the activities of the cell as well as practical benefits to humanity have followed upon the enzyme discoveries of recent years. I would remind you of only one example, that the digestive enzyme of the papaya plant, papain, is now used in America by the ton in making tough meat tender. As Balls (1938) put it, in an address to the Washington Academy of Science, ' we should probably all be surprised to know the exact number of years of beef-life that is taken out of the steaks of America by means of papain ' ; though I have a strong suspicion that knowledge of this great discovery has not yet penetrated to the roast beef of old England. As regards cell-activity the enzymes act as catalysts speeding up chemical reactions ; without enzymes cell-processes would ' proceed so slowly that the cell would die waiting for food to be digested or oxygen to become available ' (Balls, 1938).

From these few examples it is patent that much that was mysterious about life has disappeared or is disappearing before the persistent inquiries of the physicist and chemist. Life processes of the physiological order are ruled and guided by the self-same laws which regulate action in the non-living world.

But it is just as obvious that none of these interpretations reach the secret spring of life itself. The physical explanation of the architecture of animals must assume the power of the living thing to react and mould itself to the forces that play upon it ; the Donnan equilibrium, which interprets a condition of thermodynamical balance, meets the case of a living cell only when the cell activity is at its lowest, and the more active, that is the more alive a cell is, the less does the Donnan theory become applicable ; enzymes may be necessary for the complete activity of a cell, but though it may hasten a chemical reaction no catalyst can set a reaction in motion, in the case of the cell that appears to be the prerogative of ' life.'

The Quality of Life in Perspective.

Let us turn, then, from the minute analysis of the unit of life, which in recent years has done so much to reduce the mystery of life, without however reaching the kernel of the mystery, to see what suggestion may arise from another point of view, a perspective of evolutionary processes.

It is difficult for us, overwhelmed by the complexity of evolution, to single out those features which are most distinctive of life, but suppose we hand the problem over to reasonable beings of our imagination, who, coming from a world such as ours, but on which life has never existed, view for the first time the Earth. We may imagine them to be physicists or chemists or even mathematicians, for obviously no biologist could come from a lifeless world !

Amongst many wonders, two things would strike these visitors as outstandingly peculiar. The first concerns the structure of the earth's crust. In it occur unlikely accumulations which would have no counterpart in a lifeless world. Average sea-water contains only 0·12 parts of calcium carbonate per thousand, yet some forty-eight millions of square miles of the ocean floor are covered with a deep deposit of calcareous ooze containing calcium carbonate up to 90 per cent. The coral islands of modern seas, the chalk and limestone formations which represent relics of the oceans of geological times and which make up a very considerable part of the solid crust upon which we live, have been similarly abstracted and assembled by living animals from

sea-water. Soluble silica occurs in very minute quantities in the ocean, never exceeding 1·5 parts per million, yet in our present-day oceans plants have assembled from such a dilution, ten millions of square miles of diatom ooze, and radiolarian ooze accounts for another two millions of square miles of siliceous accumulations.

From the atmosphere, as well as from the ocean, unlikely aggregates have been sorted out. The average proportion of carbon dioxide in the lower atmosphere is about three parts per ten thousand, yet the superficial deposits of peat and the deeper formations of coal, oil-shale and the natural petroleum produced from them, consist essentially of carbon sorted out by plants from that tenuous store. The carbon dioxide, dispersed and inert, in 16,125,000 cubic yards of air is gathered and made potentially efficient by a single tree of some five tons dry weight.

To us these aggregates have lost all sense of wonder, but to our physicists from a lifeless world they must seem as unbelievable as the giraffe to the youngster at the zoo, for they controvert one of the established laws of physical order, that, left to themselves, units of matter in a gas or a solution move towards their maximum dispersal. The normal physical course of dispersal in the cases I have mentioned has been replaced by assortment and aggregation, and the agent of the reversal has been the living organism.

The second stumbling-block over which our visitors would trip in their prospect of the earth is supplied by the history of living things themselves. The life-history of any multicellular organism is a development, that is a selection and re-assortment of materials in such a way that the organism beginning as a fertilised ovum, already complex in a morphological and physico-chemical sense, becomes still more complex. The history of life upon Earth in the broadest sense is also an evolution from more simple to more complex. It might be said that even in the lifeless world from which our visitors came, inorganic things showed an evolution from more simple to more complex. That, for example, an ancient range of mountains, with its peaks and valleys, its corries and its precipices, is much more complex than the simple fold of the anticline which was its beginning. But that is a complexity due to disintegration, and is entirely in consonance with the physical law of randomness which would assert that in the long run the hills will be deposited in the valleys so that both will attain a common level beyond which levelling can go no further. But the complexity of the evolution of life is no disintegration; on the contrary its characteristic is integration, a building up associated with an increase in the orderly arrangement of particles, and not, at any rate as we focus our eyes upon the products of evolution, an increase of randomness.

Further, if our visitors are fortunate enough to have a biologist as their mundane guide, he will give a final shock to their physical concepts by informing them that we believe protoplasm, the essential living matter, to have arisen from a fortuitous concourse of atoms, and such an event, where physical law demands dispersal and randomness, is exceedingly improbable, though nothing is impossible. In brief, place before your physicist who has no knowledge of life, the series atoms, protoplasm, unicellular organism, metazoan, and ask him which came first ; and he will swear by all the laws of inorganic nature and statistical probability that the metazoan must have started the chain and must have evolved or disintegrated into the unicellular

organism, and that into primeval protoplasm, which must finally have dissociated into its constituent atoms. But we know that the reverse is the true sequence, the reverse of physical probability.

Is this then a fundamental secret of life, that it reverses the physical law of dissipation or increasing randomness? There has been long argument ' about it and about,' but to take recent expressions of opinion, that is the view taken by Sir James Jeans, who frankly states that ' what we describe as life succeeds in evading it [i.e. the second law of thermodynamics or the law of increasing entropy or randomness] in varying degree ' (1933, p. 276). Other writers going further see in the paradox ' the intervention and continually active interference of a guiding force which, in the case of life, lifts it into a higher plane of existence where it is not subject to the laws of entropy ' (H. V. Gill, 1933). The opposing point of view is that the processes of life offer no obvious contradiction to the second law, since if all other related and simultaneous actions be taken into account the total effect will be an increase of entropy. (See, for example, Donnan, 1934.) That may be so, but it is an unproved suggestion; and the phenomena of life and its evolution are so complex that if the resolution in terms of physical law of ' all other related and simultaneous actions ' has to be pushed from item to item until, as it were, the universe is involved before a balance can be struck, then entropy has little immediate significance for life activity.

It comes to this, that in practice the second law of thermodynamics, so well established for physical happenings, cannot be satisfactorily applied to living processes. And that while no one would deny that living things in the long run and in a universal sense are subject to its demands, and indeed that in their workings they are probably controlled by it, nevertheless organisms *appear* to be able temporarily to hold up or withstand the physical course of degradation of matter, if they do not actually reverse it.

From this point of view, then, the secret of the living organism, that is its essential difference from non-living matter, is its power of trading with its environment in such a way that it can build up its body stores of high potential energy from materials of lower potential.

So we are led to two conclusions. The origin of life must be sought in a concourse of atoms, improbable as that may seem, which traded with an inorganic environment. The first organism is unlikely to have been of the nature of a virus, although viruses have been suggested as the nearest approach we know to a primeval existence, for whether a virus be alive or be a non-living protein molecule, it multiplies by acting upon the organic materials of its host, and that presupposes the existence of other living things. It is unlikely that the first organism was of the nature of a green plant, for chlorophyll is a highly organised stuff, and although some form of energy must have been utilised in the building up of the first organic molecules, we do not know whether it was the energy of sunlight, as in photosynthesis, or of a chemical reaction like the chemosynthesis which characterises the life-processes of certain sulphur, iron and nitrifying bacteria. But even bacteria have their organisation and it may be supposed that before them there came into being pre-cellular diffuse stuffs, not yet recognisable as definite organisms, whose one outstanding character was their power of using for their own aggrandisement some form of energy about them and external to them.

A second conclusion follows upon our analysis. Phenomena of life elude treatment by the laws of thermodynamics, not necessarily because living matter does not obey these laws, but because the unknown conditioning of working organisms is too complex to yield to analysis applicable to inorganic states. Nor does it seem likely, since livingness exists within a very limited range of temperature and is readily extinguished by interferences, that it can ever be subjected to the sort of analysis which has led to the interpretation of the constitution of physical matter. It seems logical therefore to take as axiomatic the existence of life, not as a vital force which animates something different, namely matter, but as the activity of an atomic combination, the very activity of which renders it unanalysable by the standard methods of the physicist and chemist. Thus, as one of the greatest of living physicists, Niels Bohr, has pointed out, the biologist would accept for the living world a position analogous to that accepted by the physicist for the non-living. 'The existence of life must be considered as an elementary fact that cannot be explained, but must be taken as a starting point in biology, as in a similar way the quantum of action, which appears as an irrational element from the point of view of mechanical physics, taken together with the existence of the elementary particles, forms the foundation of atomic physics' (Bohr, 1933, p. 458).

And the biologist, admitting 'life,' may build up a whole body of biological theory, as distinctive and peculiarly his own, and as logical in the logic of probability which Professor Darwin advocates, as are the theories of the physicist or the chemist in their own limited fields.

Lengthening of Life Perspective.

There is another notable development of this century which must affect evolutionary thought, the expanding idea of the time during which the earth and life upon the earth have been in existence. Broadly three methods of making the estimation have been canvassed—physical, geological and biological; but from the fundamental uncertainty which attaches to conditions of life, it may be assumed that biological methods are bound to be problematical and unsatisfactory. To illustrate the enormous change in outlook which has taken place let me mention a few of the estimates.

An early estimate was biological, founded upon the genealogies of the Book of Genesis. It used to be familiar in the reference column of the Bibles of a past generation such as Bagster's Polyglot Bible, where the Creation is set down precisely at 4004 B.C. In the eighteenth century, Buffon, a far-seeing naturalist who had views upon evolution ahead of his time, put the matter to the test of experiment. Recognising in the earth a cooling body, he measured the rate of cooling of cast-iron balls, and from the results boldly stated that the six days of Biblical creation were 'periods' to be extended as the facts required, and that the age of the earth was actually some 75,000 years.

Scotland took a prominent part in the many discussions of the subject which took place in the nineteenth century. It was Lord Kelvin who, from the secular cooling of the earth, concluded that the globe must have consolidated not less than 20 millions of years ago, and finally suggested limits between 20 and 40 millions of years; and it was Prof. Tait who reduced

that estimate to from 10 to 15 millions of years. The geological view was expounded by Sir Archibald Geikie at meetings of the Association at Dover in 1899 and at Edinburgh in 1892, and he summed up for an interval of 'probably not much less than 100 million years since the earliest forms of life appeared upon the earth and the oldest stratified rocks began to be laid down.'

From these earlier discussions it would appear that a psychological element entered into the final estimates, as if the calculators drew back aghast at the possibility of the enormous age of the earth at which their estimates hinted. Thus almost all tended in their final summing towards the minimum of their scales, and little is heard of the other extreme—Lord Kelvin's independent maxima, reached by different methods, of 1,000, 400 and 500 million years, or Geikie's 400 million years—although these came much nearer to the modern estimate.

The effect upon the biologist of the varying estimates, of their uncertainty and the adverse criticism to which they were subjected, was such that he simply ignored them. Thirty years ago it was the worst possible form, zoologically, to mention them. But now, thanks to a consensus of opinion that admits credibility to estimates based upon the break-up of radio-active minerals in the rocks, the reputed ages of the geological formations are creeping, somewhat apologetically, into the biological textbooks. They have passed through the textbook needle's eye ; that is a sign for anyone to read.

Some of you will remember the joint discussion, shared in by this Section, at the meeting of the Association in Edinburgh in 1921, when Lord Rayleigh summarised the physical evidence from the breakdown products of uranium. Since then the methods of estimation and calculation have been refined, but the results of several methods appear to be in substantial agreement. Thus the beginning of the Cambrian formations, with their well-preserved fossils, were laid down probably about 500 million years ago ; below the Cambrian are formations with relatively few and mostly ill-defined fossils, which carry the relics of life back some 800 million years, and stretching away beyond that we must imagine a period when life was evolving in its most primitive forms, of which no trace remains or could remain. We may say that life has existed upon the earth for perhaps 1,200 millions of years ; and then to complete the picture that the birth of the earth, and as the new cosmology seems to indicate, perhaps also at the same time the stupendous birth of sun and stars, took place about 2,000 million years ago.

Stability of Organism and Slowness of Evolution.

This amazing extension of the time concept of life emphasises anew some of the striking features of evolution. We are accustomed to lay stress on the variation of living things, upon which evolution depends, but surely more remarkable is the stability of living organisms, which retain their own characters in spite of changes in the environment, and whose germ cells pass these characters unaltered through countless generations. The edible cockle (*Cardium edule*) has retained its specific characters for two million years or more ; its genus, in a wide sense, lived 160 million years ago in the Trias.

The Crinoid genus *Antedon* which flourishes in our own seas antedated that old bird *Archaeopteryx* in the Jurassic Period, 140 million years ago. It is surprising enough to realise that genera of foraminifera, like *Nodosaria* (Silurian) and *Saccammina* (Ordovician), still abundant in our oceans, have retained their generic characters for about 300 million years. But they are relatively simple organisms ; it is still more astonishing to think that contemporaneous with them or before them lived modern genera (again in the wide sense) of more highly organised brachipods, like *Lingula* (Ordovician), and *Crania* (Ordovician), and that these have experienced the geological upheavals and secular changes since Palæozoic times without turning a hair, or in the revised version, without the shift of a gene upon a chromosome.

It is in agreement with that stability of organisms that we must conceive of evolution as a process of extreme slowness, as if living things are loth to change, and ultimately change only under the direct compulsion of circumstances. Of that slow progress in its minor phases the new chronology gives us a measure. One or two well-known examples will illustrate the point. Osborn (1918) and Matthew (1914), each in his day, suggested a time-scale for the evolution of the modern Horse (*Equus*) from its precursors of Eocene times. But the newer data bearing upon geological ages should contribute further precision to a fresh estimate. Accepting, then, the data from helium and lead methods of time-estimation as given by Holmes (1937), we find that the whole gamut of changes which modified the four-toed foreclimb of *Eohippus* into the single toe of *Equus*, from Lower Eocene to Upper Pliocene, occupied about 57 million years. It took some 17 million years to reduce the four effective digits of *Eohippus* (Lower Eocene) to three in *Mesohippus* (Lower Oligocene), and 22 million more to raise the two lateral digits clear of the ground (in *Merychippus*, Middle Miocene). The penultimate stage of reducing the ineffective side digit to vestigial splints (in *Plesippus*, Upper Pliocene) occupied some 16 million years, and the gradual reduction of these vestiges to the condition seen in the true horse (*Equus*, Upper Pliocene) probably took about another two million more.

Time evolution in the series of invertebrate animals may be illustrated from A. W. Rowe's well-known study (1899) of the unbroken gradation of variations in the fossil sea-urchin *Micraster*. The Cretaceous period occupied in all about 40 million years. A rough proportional estimation would suggest that the evolution of the foundation species of the series *Micraster cor-bovis* into *M. cor-testudinarium* (i.e. from the *Terebratula gracilis* zone to *Holaster planus* zone) took about one million years, while the further changes which eventually produced *Micraster cor-anguinum* occupied an additional 1½ million years.

From another standpoint a view may be gained of the rate of evolution in recent times. The American scientist O. P. Hay stated in 1928 that ‘ a learned writer on mammals tells me that he doubts that a single new species has developed since the first interglacial stage.’ But the suggestion is incorrect. In the outer islands of Scotland there are recognised several species which are distinctive of the islands, such as the Islay shrew (*Sorex granti*), the Orkney vole (*Microtus orcadensis*), the Mull bank vole (*Evotomys alstoni*), the Hebridean field-mouse (*Apodemus hebridensis*), or its relatives in Fair Isle (*A. fridariensis*) and in St. Kilda (*A. hirtensis*), and the St. Kilda house-mouse (*Mus muralis*)—to take examples from several different genera. We need not discuss the special

characters of these species, it is enough that they are recognisable and are regarded as distinctive by the specialists best qualified to judge.

Now a time limit is set to the evolution of these species. Scotland itself and its islands were overwhelmed with glaciers during the Ice Age, life was extinguished, and it was only after the ice had passed away and the land had subsequently become clothed with vegetation that the country became fit for even shrews and rodents to live in. The mainland of Scotland was stocked by migration from the continent of Europe, the islands presumably from the mainland, and since that time the new species of the islands have branched off from their mainland ancestors. All this must have happened in a period subsequent to the last great glaciation. Penck reckons the Buhl stadium of post-glacial time in Northern Europe at about 20,000 years B.C., and that probably indicates the maximum of time which may be allowed for the evolution of the Scottish island species.

It is natural that the degree of change involved in the transformation of those species cannot be compared with the generic changes in the horse series, reckoned in their millions of years ; and yet it is plain that the comparatively slight changes shown by the endemic species of the Scottish mainland and the islands, as well as many less marked changes seen in the geographical races of Scottish birds and mammals, while of post-glacial origin, have had available for their development a range of years far exceeding the span of human observation or tradition.

If this time-factor is a necessary element in the evolution of species in nature, doubt is thrown upon the validity of arguments concerning evolution based upon laboratory experiments in which intensification of means produces rapid change. There is no reason why the reaction of an organism under such exaggerated stimuli should be the same as that produced by minimal influences of the same nature over an exceedingly long time. Even in inorganic nature the reaction of inanimate environment may differ according to the time element. A new stream makes its way along fissures and weaknesses in the substratum on which it flows, and this first course may determine the meanderings of the stream through long ages. But concentrate the flow of a year or several years in a cloud-burst which falls at the source of the stream, and the track made by the torrent, cutting across obstacles, may bear no resemblance to the age-worn course, except that it runs down-hill. The sensitive organism delicately adjusted to a particular environment is less likely than inorganic environment to give a ' natural ' answer under concentrated compulsion.

Advent of Man and Evolution.

The lengthening of the time perspective of life upon the earth adds new insignificance to the span of man's tenancy of the world and new impressiveness to the part he has played as an agent in evolutionary processes. Man of our own genus, beginning in the early Pleistocene Period, has probably less than a million years behind him, but the species of man now dominant in the world (*Homo sapiens*) appeared only at the close of the Würm Glacial stage, no longer than 25,000 to 40,000 years ago. Yet even this relatively short space of time exceeds man's span as an effective agent in world change, for in spite of the arts he developed in early post-glacial times he remained practically submerged

in the fauna, having little more influence upon his environment than the beasts with which he shared it.

> 'Man walked with beast, joint tenant of the shade;
> The same his table, and the same his bed.'

It was Neolithic man who set the ball a-rolling through his outstanding achievements in domesticating wild animals and in developing the cultivation of the soil and growing of crops. For these achievements, apart from laying the foundation of a new era in the progress of civilisation, started a series of changes which have profoundly influenced the distribution of life upon the earth. In one direction the safety of flocks and herds demanded the elimination of beasts and birds which threatened them, and in another the need of land for crops and pasturage played havoc with the wild environment and so with the fauna which it sustained and sheltered, although the crops themselves encouraged the multiplication of certain elements in the fauna which became the pests of agriculture.

The Neolithic Age, which originated these changes, reached Western Europe only some 8,000 years B.C., though in the East and in the lands of old culture it began several thousands of years earlier. But Neolithic man, although he initiated the most far-reaching changes in plant and animal life, was himself, with his implements of wood and stone and limited powers of offence, ineffective in his interference. Even in a limited area like Scotland, few animals died out during his rule and it would be difficult to bring home to him responsibility for their disappearance. For the effective introduction of man as an agent of evolutionary change we must look to a time more recent. And that time is determined by his increasing efficiency as a cultivator and destroyer, and particularly by the need for food and fire demanded by an increasing population. These influences began to make their mark about the tenth century of our era when several of the interesting members of the primeval fauna of this country had disappeared or were on the verge of extinction, but in the centuries following the sixteenth they commenced a period of pressure, which, increasing in intensity, has transformed the faunas of civilised lands.

It is not an accident that the emergence of man as a major factor in the evolution of faunas coincided with the increased power of destruction presented to him by the invention of gunpowder and guns, and with that extraordinary increase in population which in the last three hundred years has multiplied, almost five times over, the numbers of mankind upon the earth (see Pearl, 1937). For this burst of population was itself the accompaniment of intensified agriculture and stock-rearing, of the spread of industries and development of commerce, all of which have had profound repercussions upon aboriginal faunas and floras.

While modern man has existed upon the earth for some 30,000 years, his part as a distinctive agent in the evolution of faunas is limited to a thousand years, and within that span his great transformations are practically confined to the last three hundred years. That is a period infinitesimally short compared with the ages during which the aboriginal faunas into which he was launched had been differentiating, redistributing and establishing themselves in a natural balance. What transformations has he wrought in so short a time?

The lengthening perspective of life upon the earth gives new significance to the extent of man's interference.

I do not propose here to examine in detail the magnitude of this new world factor in the evolution of faunas and floras. That is best shown in a limited area which can be intensively studied, and I have elsewhere described with reasonable thoroughness the stages and sum total of this process in Scotland, the recent geological history of which makes it particularly suited for such an analysis (Ritchie, 1919, 1920, 1923). I may, however, indicate the depth of penetration of this new faunistic factor by pointing out how superficial is the view that regards man merely or mainly as a destroyer. He has indeed deliberately reduced numbers or extirpated animals for his own protection or for that of his flocks and crops, for food and other necessities, for sport, and to satisfy the whims of luxury; and without intention his cultivation of plains and marshes and destruction of primeval forest have destroyed feeding grounds and banished their former tenants. Yet his addition to numbers far outweighs his destruction. Intensive cultivation has added a stock of domestic animals far beyond the bearing capacity of wild country, besides increasing the numbers of wild creatures which also benefit from his crops. Deliberate protection of animals, for sport, for utility, for æsthetic reasons, and on account of popular superstition, has also multiplied numbers. Furthermore, apart from numerical changes within the aboriginal faunas, man has changed their qualitative composition by introducing foreign animals deliberately (here we must include domestic animals), and unintentionally through the ramifications of international commerce.

These are simple primary effects of man's interference; secondary and remote consequences are even more impressive in their ultimate issues. In general it may be said that wherever civilisation has made itself felt three main faunal changes are noticeable: the largest animals tend to be reduced in numbers and eventually to disappear; smaller creatures, dependent upon cultivation and human habitations, multiply far beyond aboriginal numbers; and the deliberate or accidental spread of 'foreign' creatures is creating a degree of cosmopolitanism throughout the world's faunas.

How do these changes brought about by man stand, viewed in the perspective of the long evolution of faunas upon the earth? There are two types of change in progress in the natural assemblage of animals in any region. There is a constant ebb and flow within the fauna itself due to local and temporary influences, a swing of the pendulum about a mean, the 'balance of life' which is never quite struck. But there is also a faunal drift, revealed in the story of the rocks or in any long vista of faunal history, and this is due to great secular changes, to geological influences, to modifications of climate, to the insurgence of the forces of life.

Where man's interference is temporary and casual it may be compared to the internal faunal tide, which is of little moment in the long run; but where his interference is persistent in any direction it must be reckoned as sharing with the great secular forces of Nature in propelling a fauna upon a path along which there is no return.

Such is the remarkable conclusion to which the long view of man's place as a natural agent brings us—that he has set in motion forces which, in our era and mainly in the last three hundred years, have wrought faunal changes

which can be compared only with the great secular changes of world evolution. And when the ridiculously short span of his interference is contrasted with the slowness of natural processes, the probability forces itself upon us that in a few more thousand years of man's inheritance of the earth the old order of nature will be superseded in the faunas of the world by a new order of Mankind.

Man in Evolutionary Perspective.

Having thus assigned to Man dominance amongst the forces which determine faunal assemblages, let me now endeavour to put him in his place in the long perspective of life and evolution.

Temporarily his past is insignificant, how insignificant it is almost impossible to realise. But let us picture the unimaginable space of time since life began as a twelve-hour day, beginning with the first living molecules in an early world at midnight and reaching a climax, as we should say, at the high noon of evolutionary attainment—ourselves. These twelve hours will represent, according to the data I have already referred to, roughly 1,200 million years, each hour 100 million years, each minute rather more than 1½ million years. Our clock must be a twenty-four hour clock, for we can assume that life and evolution will continue in the future (for the convenience of my diagram, supported by the calculations of the physicists) say as long as life has already existed. Then the long period of indeterminate living things almost unrepresented by fossils would have existed from zero till 7 o'clock ; the Palæozoic period, when fishes and amphibia predominated, till about 10 o'clock ; the Secondary period with its predominant reptiles till about 11.15 ; and the great development of birds and mammals in the Tertiary period would be confined to less than three-quarters of an hour before mid-day. Now in this procession primitive man makes his appearance with the Ice Age at less than a minute to noon, and man of our own species (*Homo sapiens*) less than a second and a half ago. On our time-scale all the developments of historic man, all the wonderful achievements of civilisation, all the new order of mankind in nature has been crowded into less than one-tenth of a second.

But this perspective of man's temporal place in the universe suggests other considerations. It gives a pointer to the future of mankind upon the earth. Prof. Julian Huxley in his address to this Section of the British Association at Blackpool (1937) and many others have speculated upon the near view of man's future. To some it has seemed likely that future progress will be along the lines of individual development, that brains and mind will become more perfect in their working until man is master of all nature. Others look to a future in which not the individual as a unit, but society as an integration of individuals will become more closely knit and more perfect in its functioning.

Still others see in the modern developments and threats of warfare a warning finger of the doom of civilisation. I would remind these doubters that evolution as we know it is built upon destruction ; that the development of the whole animal kingdom rests upon the destruction of green plants, which biologically are formed of the same stuff as we are, and that within the animal kingdom

the flesh-eaters have risen upon the bodies of their fellow-creatures. The drama of wars amongst mankind and the imminence of war seizes the imagination, and history-books bias the mind by emphasising wars and ignoring the quiet but effective work of millions of unknown citizens through the ages. But in our perspective of hundreds of millions of years these are the merest incidents and, war or no war, the quiet progress of evolution flows through life carrying the world of living things steadily but unobtrusively from one step to a higher.

In his short past man has been moving towards a higher intellectual, spiritual and moral standard, and the biological view would be that in the immediate future (geologically speaking) that movement will continue and that for human beings this future lies in the development and perfection of social life and in the spreading of the social idea to include peoples and nations as well as individuals, with all the correlated advances that these imply.

That is the short view of man's future, but what of the long view of mankind upon the earth? I notice that Sir James Jeans contemplates (1929, p. 338), at any rate fancifully, the existence and progress of humanity until the shadow of the extinction of life upon the earth falls upon the world, many millions of years hence. Does our vista of life support such a view?

We must admit that any view of science about the future of humanity can be only a short-range forecast; of the long-range forecast it can say nothing. The reason is that science knows only the past and the present, so that it can read into the future only the glorification or degradation of what has already been expressed in mankind, let us say better brains, better social organisation, less self-seeking. Yet the unfathomable characteristic of life is that it is always throwing up something new; evolution proceeds not only by permutations and combinations of the old, but by the emergence of new lines of development. The physicist can foretell with accuracy the movements of the planets, the return of eclipses and comets, but who knowing only fishes could have foretold the amphibia which arose from them, or knowing only the reptiles could have foretold their descendants the birds and the mammals? When we leave details, in the world of living things we can be wise only after the event, we cannot be wise before the event. Therefore the long future of evolution upon the earth is unknowable, so far as science is concerned.

Nevertheless, bearing that warning in mind, we may gain some hint from our perspective of life upon the earth.

We look upon man, and rightly so, as the crowning glory of evolution: stage by stage, we say, the evolution of the past has led up to him; we can imagine nothing higher, evolution appears to have reached its goal.

But step back some 180 million years in our time-scale to the Triassic period when the great dinosaurs dominated the earth and nothing higher than Reptiles had been evolved. To themselves and to the creatures which shared the world with them, they must have seemed (if they had any self-consciousness), and indeed they were, the crowning glory of creation; stage by stage the evolution of the past had led up to them; nothing higher could be imagined, evolution appeared to have reached its goal. And that could be said by their contemporaries of the highest creatures at every stage in the course of 1,200 million years of evolution, just as it is said of Man to-day. A hundred million years have rolled past since the time of the dinosaurs and they and all

their immediate kin have disappeared for ever, and new and unforeseen trends of life have blossomed, as they have done over and over again, and have carried the story of evolution on to the present, when man is the dominant and highest.

Looking back over that 1,200-million-year vista of the steady climb of life upon the path of evolution, it seems presumptuous for us to suppose that man, the latest newcomer, is the last word or the final crowning glory amongst many, and that with his coming the great steps in evolution have come to an end. Looking forward to the future of life upon the earth, it seems even more presumptuous for us to suppose that for the next 1,000 million years life, so surprisingly inventive in the past, should be tied for all time to come to trifling changes like increase of brain power or better social organisation for mankind.

The truth is that we, bound by the past, can imagine nothing more, but if the long vista of evolution is any clue to the future, we cannot regard mankind, the crowning glory of the present, to be more than a stage in life's progress and a milestone upon the path of evolution towards a greater future. To think otherwise is to imagine that with the coming of man, so insignificant in time, the advance and inventiveness of evolution, steadily carried on through an unimaginable vista of years in which no trace of slackening can be perceived, has all but come to an end.

It may seem to you that our perspectives have carried us far afield into a future so remote that it is scarcely worthy of consideration. My excuse must be that we are so accustomed to think of man as the sole significant inhabitant of the world that it is worth while now and again to look upon him in his biological setting as but one, and yet so far the greatest, of the manifestations of life upon the earth.

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SECTION D.—ZOOLOGY

COMMUNICATIONS

Dr. R. S. Clark.—Movements of herring larvæ.

The observations are based on material collected by the Scottish research vessels since 1904, but excluding the war period, within the area bounded by latitudes 53° and 63° N. and longitudes 8° E. and 10° W. The plankton collections averaged about a thousand a year and the number of Clupeoid larvæ sorted out, identified and measured, totalled about a million. The origin points of the larvæ, both in time and place, were defined by a combination of the following methods:

1. Dredging of eggs *in situ.*
2. Occurrence of eggs in stomachs of predaceous fishes.
3. Capture of yolk sac larvæ.
4. Concentrations of spawning shoals.

The larvæ, after the absorption of the yolk sac, rise to the surface layers and are carried passively downstream by the currents. The actual numbers caught were greatest at sizes less than 15 mm., but they decreased rapidly with growth and with dispersal over a wider area. The numbers of larvæ over 20 mm. in length were relatively few in the collections, the immediate pre-scaled stages being found mostly in coastal waters, and the smallest scaled stages within the bays and in the estuaries. No seaward migration of any magnitude of the larger and older larvæ was observed.

Dispersal of the larvæ bears a definite relation to the main current systems, but complications may arise from swirl currents which vary in extent seasonally and annually.

Diurnal vertical migrations occur as in adult fish.

Mr. J. H. Fraser.—Animal indicators of Atlantic flow into the North Sea.

Water entering the North Sea can be distinguished from North Sea water by physical differences and also because it brings with it a different plankton. Different species have differing habitats and so a knowledge of the actual species will reveal, within broad limits, the origin of the incoming water. Typical indicators of warm water are Salps, Doliolids, Velella, *Sagitta serratodentata*, Eukrohnia, Rhincalanus and Eucalanus, and typical of cold water are *Calanus hyperboreus*, *Metridia longa*, *Sagitta elegans arctica* and *Limacina helicina.* Similarly, upwelling of deep water will bring into the surface layers deep-water species such as *Sagitta maxima* and *S. lyra.* As the Atlantic inflow passes round the north of the British Isles and into the North Sea it becomes more and more influenced by admixture of coastal water; the purer

oceanic forms die out and become replaced by a rich mixture of abundant *Sagitta elegans*, Calanus, Euphausids, Medusæ, etc. This mixture is one of the richest plankton communities around the British Isles. North Sea water is typified by the presence of *Sagitta setosa* and has a comparatively poor plankton population. By studying the distribution of these species, the course and extent of the penetration from year to year may be traced.

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Mr. C. E. Lucas.—An investigation into the ecology of plankton in the North Sea.

In 1932 Prof. A. C. Hardy described to Section D the initiation of a survey of the plankton of the southern North Sea by means of the Continuous Plankton Recorder. This began at University College, Hull, in 1931 and provided continuous records of the plankton monthly between Hull and Bremen, Copenhagen and Rotterdam and, later, between London and Esbjerg. This work was expanded in 1937 to include the northern North Sea, a second laboratory being opened at Leith as a base for further lines between that port and Copenhagen, Hamburg, Lerwick and Faroe and from Glasgow to Hamburg and Bergen. From these ten lines a monthly network of observations is obtained for the study of the seasonal and annual variations of the plankton.

This communication concerns mainly the results from Scottish waters, in which work Mr. N. B. Marshall and Mr. C. B. Rees have also shared. It is based on some 25,000 miles of recording in 1938 and 1939 and shows representative surveys of the distribution of different zoo- and phyto-planktons. The bearing of the data on knowledge of water movements and commercial fisheries is discussed. From such regular observations it is hoped that, rather like a meteorological service, it may be possible to provide working forecasts of subsequent conditions.

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Mr. R. D. Purchon.—The biology and relationships of *Xylophaga dorsalis*, a wood-boring mollusc.

Previous workers, who examined only the shell, accessory plates and pallets of *Xylophaga*, considered that *Xylophaga* more nearly resembled the rock-borers such as *Pholas*, than the other wood-boring Lamellibranchs.

Examination of the soft parts reveals that *Xylophaga* is intermediate in structure between the Teredinidæ and the Pholadidæ, having many points in common with both of these families. It is more nearly related to the Teredinidæ, however, and should be transferred to this family. This decision is supported by an examination of the ctenidia, labial palps, alimentary canal, pericardium and the musculature.

Xylophaga also resembles other wood-boring Molluscs in being a protandric hermaphrodite. It possesses a pair of vesiculæ seminales which are situated close to the openings of the genital ducts. It also possesses an extraordinary glandular organ in the supra-branchial cavity. It occurs in an active condition only during the male phase, and is thought to assist in the storage of spermatozoa in the seminal vesicles. This is the first recorded case of sexual dimorphism in the Lamellibranchia.

Self-fertilisation, which is certainly made possible by the possession of these organs, would be of great survival value to these animals which are usually found in small pieces of driftwood.

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Discussion on Aspects of parthenogenesis.

Prof. A. Vandel.—Polyploidy and geographical distribution.

The author has previously pointed out that two races or two neighbouring species, of which one is bisexual and the other parthenogenetic, often occupy different

geographical areas. Generally, the parthenogenetic race inhabits more northern regions than the bisexual one. The parthenogenetic race is generally also polyploid compared to the bisexual race. The author called these facts 'Geographical Parthenogenesis.' The researches made by the botanical cytologists have led the author to modify his first interpretation, for they have shown that polyploid plants are more numerous than diploid ones, not only in the arctic or alpine regions, but also in regions with unfavourable climate (desert type) or in soils unfit for plant growth, e.g. those rich in lime or in salt. In a word, polyploids seem more resistant than diploids to unfavourable conditions. The author applies these conclusions to 'Geographical Parthenogenesis' and considers that the extension of parthenogenetic and polyploid forms towards the north is linked more to their polyploid state than to their parthenogenetic multiplication. For instance, in one of the terrestrial Isopods of the genus *Trichoniscus*, the parthenogenetic form not only extends further north than the diploid form, but is the form which inhabits the Mediterranean 'garrigues,' very dry places, nearly at the limit of the possibility of life of *Trichoniscidae*. These facts agree with those shown by the botanists and prove that, because of their stronger resistance, the distributional area of polyploids is larger than that of the diploids.

Dr. Ann R. Sanderson.—The cytology of parthenogenesis in the snail *Potamopyrgus jenkinsi* Smith.

Only two parthenogenetic snails are known, *Potamopyrgus jenkinsi* Smith (sometimes referred to as *Hydrobia jenkinsi* or *Paludestrina jenkinsi*) in Great Britain, and *Campeloma rufum* Haldeman in North America. The cytology of the latter species, worked out by Mattox, shows that the parthenogenetic egg does not undergo reduction and that the diploid number of chromosomes is 12. In Scottish forms of *P. jenkinsi*, a second method of autoregulation occurs, for the egg undergoes one, non-reductional, division, the diploid number being 36–44. As Rhein states that on the Continent the species has a diploid chromosome number of 20–22, it is possible that the species in Great Britain is polyploid (tetraploid) and illustrates geographical parthenogenesis.

Miss M. C. Malcolm.—Recent cytological studies in saw-fly parthenogenesis.

The paper summarises the findings made by a number of workers at Dundee. In species so far investigated, the commonest diploid chromosome number is 16, but diploid numbers of 14 and 12 also occur. Studies in chromosome individuality support the postulate that the male and female, usually regarded as haploid and diploid respectively, are actually diploid and tetraploid ; this may account for the unusual viability of the male. Where parthenogenetic development is male-producing (arrhenotokous), maturation in the egg is normal, the production of females being dependent on fertilisation. In female-producing (thelytokous) parthenogenesis, there are two methods whereby the normal chromosome number is secured : (*a*) only one maturation division occurs, synapsis being absent, and the normal number being maintained, e.g. *Thrinax macula* Kl. ; (*b*) two maturation divisions involving reduction occur, the normal number being restored by fusion of the egg pronucleus with a polar body nucleus, e.g. *Pristiphora pallipes* Lep. Certain biological and cytological abnormalities have been found : (*a*) In *Priophorus tener* Zad., which normally shows arrhenotokous parthenogenesis, parthenogonic females have been produced. (*b*) Gonads, female in gross appearance, yet containing male cells, have occurred in *Pristiphora pallipes* and *Trichiocampus viminalis* Fall. The implications of the above are briefly discussed.

Prof. A. D. Peacock.—Recent researches in experimental parthenogenesis. A review.

The pioneer classical experiments of Loeb and Bataillon, some forty years ago, demonstrating that unfertilised eggs could be artificially stimulated to development, excited much research which has shown that the capacity for parthenogenetic development in animals is much greater than formerly supposed and that experimental parthenogenesis can be induced by very many methods. Experimentation has also thrown much light on fundamental phenomena such as the functions of the nucleus and the cytoplasm, on the constitution and functions of the reproductive cells, and on the 'setting going' of processes (activation) which initiate the development of unfertilised eggs. Nevertheless there still exist many limitations in our knowledge. The types that respond to experimental treatment are mostly aquatic, yet, as the majority of parthenogenetic animals are terrestrial, the results discovered for aquatic forms are of limited application. Many of the types studied actually show rudimentary parthenogenesis, while only in rare cases have adults been reared and their sexes determined. Cytological knowledge is also patchy and incomplete. No common activating principle has been discovered in the many agents used, nor has the nature of activation. There is uncertainty regarding the identity of the mechanisms of experimental parthenogenesis with those of fertilisation and of natural parthenogenesis and experimental methods have not revealed the origin and cause(s) of natural parthenogenesis.

Discussion on The habits of salmon and trout.

Mr. W. J. M. Menzies.—Salmon migrations.

Clean salmon marked in the Moray Firth have been found to be in the neighbourhood of the river up which they will ascend, the majority of movements being confined to within an area of 50 miles of the place of marking. From the west coast of Scotland between Loch Inchard (20 miles south of Cape Wrath) and Ardnamurchan Point, the majority of marked salmon have travelled to the north and east coasts up to a distance of 400 miles from the point of origin. These fish have completed their feeding period before they reach the coast.

In Norway, salmon marked close to the mouth of the fjords have moved inwards and up the fjords. But salmon marked on the shores of the outer island belt have made migrations analogous to those of the salmon on the west coast of Scotland. From the neighbourhood of Bergen they spread both southwards and northwards, one going as far as the White Sea. From a station near the North Cape two classes of movement were exhibited, one a local movement within about 100 miles of the place of marking, and another a very extended migration right along the north coast of Europe as far as the River Petchora, reputed to be the eastern limit of Salmo Salar.

Mr. P. R. C. Macfarlane.—Homing instinct of the salmon.

Scale reading has shown that the salmon of different rivers vary in certain characteristics; for example, in the average age and length of the smolts and the proportions of the various age groups which make up the stock. Among the salmon of each individual river these characteristics remain relatively constant from year to year, while the differences exhibited by the fish of even neighbouring rivers are equally regular. That the salmon of each river should form a separate biological unit might be explained if the particular feeding grounds in the sea to which the salmon of any one stream resort were in the near vicinity, and within the sphere of influence, of that stream. Marking of salmon has proved, however, that they migrate in the sea to very great distances from the rivers to which they ultimately

return. The smolts from the various rivers, therefore, must form, in the sea, a population of completely mixed characters, and the returning adults, were they indiscriminate in the selection of the stream which they ascend, would produce in each river a stock identical in all particulars. That this is not the case points clearly to the possession by salmon of a strongly developed homing instinct. This is borne out by the mass of evidence obtained from the marking of smolts and kelts.

Dr. K. Carpenter.—Seasonal rhythm in the feeding of salmon parr in the Cheshire Dee.

A report of conclusions drawn from the examination of stomach contents of monthly samples of fishes obtained from the Dee and its tributaries, in connection with work being done at the University of Liverpool on the life-history of the Dee salmon.

Mr. R. M. Neill.—Food relations of the trout.

Prof. J. H. Orton and Mr. J. W. Jones.—The spawning and post-spawning phase in male salmon parr and smolts from British rivers.

Mr. D. F. Leney.—Modern hatchery methods.

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Exhibition of Biological Films. (*By courtesy of Strand Film Zoological Productions, Ltd., Gaumont-British Instructional Films, Ltd., and Associated British Film Distributors, Ltd.*)

Dr. J. S. Huxley, F.R.S.—Animal legends. The mind of the black-backed gull.

Mr. H. R. Hewer.—Crustacea. Arachnida. The Grey Seal.

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Prof. Sir D'Arcy W. Thompson, C.B., F.R.S.—The mechanics of the bird's skeleton.

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Mr. C. W. Parsons.—The embryology of the Hoatzin.

Hoatzin (*Opisthocomus*) embryos are of special interest because the type is the only one of its family and sub-order, and is well known to possess important anatomical features comparable with the bird-like reptiles. Eleven Hoatzin embryos collected by Dr. Carter in British Guiana have been examined. These range in development from a stage having nine mesoderm segments—equivalent to a fowl embryo of approximately forty hours' incubation—to one single specimen ready to hatch. The earlier embryos resemble the corresponding stages in the development of other birds, but the oldest embryo is characteristic of the type and has been dissected. Points in the anatomy of this specimen and their bearing on previous observations on Hoatzin embryos are discussed.

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Dr. G. H. Edington and Miss A. E. Miller.—A comparative study of the ulna in birds.

Owen referred to certain bony outgrowths of the ulna in birds as 'quill knobs.' These vary in different species and an account of their differences in certain instances is given. A large number of wing skeletons from museum preparations have been examined in addition to fresh material. In order to ascertain the relations of the secondary quill feathers to these structures, sections of adult ulnæ and of younger stages have been examined and compared histologically. The structures themselves have been investigated in order to record the course of their development.

Prof. L. T. Hogben, F.R.S., and Mr. F. W. Landgrebe.—Visual acuity in fishes.

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Mr. H. Waring.—Chromatic behaviour of the freshwater eel.

Eels pale on an illuminated white background and darken on an illuminated black background. Eyeless animals, and normal animals in total darkness, are an intermediate shade. Chromatic behaviour of eels is slow and is co-ordinated by two hormones—an expanding hormone (B) from the posterior lobe of the pituitary and a contracting hormone (W) from the anterior lobe. Hypophysectomised eels show a small measure of background response which is rapid. Co-ordination of this response is by direct innervation of the melanophores.

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Mr. G. P. Wells and Miss I. C. Ledingham.—Action of hypotonic salines on the isolated tissues of polychæte worms.

Various workers have studied the osmotic pressure of the body fluids in marine and estuarine invertebrates (especially crustaceans and polychætes) in relation to that of the external environment, and have shown that the invasion of brackish and fresh water is correlated with the ability to maintain a blood salinity higher than that of the surrounding fluid. There has, however, been little work on the osmotic pressure tolerance and relations of the actual tissues of the animals. The existence of this gap in our knowledge is regrettable, for we cannot appreciate the significance of an internal environment without a knowledge of the requirements of the cells for whose protection it is maintained. The authors have therefore made a study of salinity effects on the activity of isolated rhythmic preparations from polychæte worms. The tissues were exposed, *either* to sudden changes of salinity *or* to salinities which ' drifted ' slowly and steadily, over periods of many hours, from that of sea water down towards that of fresh water. The ability of many types of cells gradually to accommodate themselves to a new environmental osmotic pressure, with the consequent differences in effect between sudden and slow salinity changes, are emphasised in discussing the results.

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Mr. J. W. Morton.—The reaction of retinal pigments to coloured light.

The paper gives a short account of research on colour vision being performed in collaboration with Prof. Fritz Weigert.

The method used is one developed by Prof. Weigert and depends on the phenomenon of photo-dichroism in thin films coloured with photo-labile pigments. This has been applied with success to the investigation of extracts from the retinæ of cod, dogfish and frogs. The results so far obtained would seem to give a basis for colour vision of a purely physical nature when considered apart from the psychology of this function.

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Mr. L. C. Beadle.—The biology of some saline waters in the Northern Sahara.

Owing to the peculiar geological structure of Central North Africa, the Northern Algerian Sahara forms a closed drainage basin in which water collects by subterranean courses both from the north and the south. There are several isolated patches of open water, some of which are permanent, which tend to become saline owing to evaporation. They are often saturated. The colonisation of these by living organisms presents problems of great interest to the ecologist, the physiologist and to the student of geographical distribution. The animals and plants are mainly of fresh-water origin, but several species are only known from inland saline waters. Others are also found in the sea and estuaries, and it is possible that some of these

are marine relicts from a time when the sea invaded the Northern Sahara. The physiological mechanism of adaptation to high salinities has been investigated in the mosquito larva *Aedes detritus*, which can tolerate anything from a trace of salt to a concentration at least twice that of sea water.

* * *

Miss I. Limbert.—A comparative study of the food of freshwater fishes with special reference to the Tweed.

Collections from the Tweed watershed have made possible some studies of the food of four species of non-salmonoid fishes.

Spring-caught grayling were feeding more heavily than those taken in the autumn. The stomachs of both groups contained a great variety of animals. Subsurface forms constituted 94 per cent. of the total food organisms, the remainder consisting of surface types. The dominant foods vary in different areas. Tweed grayling were feeding mainly on larvæ and pupæ of Chironomidæ to the extent of 50 per cent. of the total food, Derbyshire grayling on *Planorbis* sp. and Hampshire grayling on *Gammarus pulex* L. The importance of *Gammarus* in the food appears to decrease northward, that of some other organisms to increase.

Flounders from the Tweed were apparently restricted to small food animals by the size of their mouths. Larvæ and pupæ of Chironomidæ constituted 98 per cent. of the food.

Roach taken in the Tweed watershed in September and May were feeding on plants of which *Oedogonium*, *Cladophora*, and numerous diatoms were the most abundant. Animal organisms were extremely rare.

Stomachs of gudgeon caught in May contained chiefly vegetable débris of the same type as in the roach, although the proportion of animal remains was somewhat larger.

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Dr. E. B. Worthington.—Recent developments in research on freshwaters.

Three examples of research being conducted at Wray Castle, the central laboratory of the Freshwater Biological Association, are described briefly.

1. In order to understand the present and future potentialities of a body of water in regard to the production of life it is advantageous to have knowledge of conditions in the past. The deposits on the floors of lake basins provide some information and accordingly they are being studied in the English lakes : echo-sounding machines give information on the thickness of deposits, special apparatus for raising cores provides a check on the records from echo-sounding, and microscopic examination of the cores indicates the succession of diatoms and other forms which have lived in the lakes since the Ice Age. 2. Knowledge of the seasonal cycle in productivity of the open water, formerly restricted to physical and chemical variables, algæ and zooplankton, is now made more complete by the study of bacteria. Variations in numbers of bacteria at different depths throw new light on biological activity. 3. The factors concerned in the growth-rate and size attained by fish are of both scientific and economic importance. Coarse fish, salmon, and trout are under investigation and a few results are put forward, especially regarding the latter.

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Dr. J. D. Robertson.—The biological importance of calcium in natural waters.

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Mr. G. W. Rayner.—Preliminary results of the marking of whales by the Discovery Committee.

Between 1934 and 1938 the Discovery Committee pursued an intensive programme of whale marking on the whaling grounds of the Antarctic, effectively

marking more than 5,000 Blue, Fin and Humpback whales. Of these about two hundred have been reported as captured after intervals varying between one day and fifteen hundred days. The data obtained are yielding much new information bearing on the life histories of the commercially important whales and the effect of the industry.

The migratory movements taking place are shown to consist essentially of a return to the same area of the Antarctic year by year. In the Humpback an annual migration to tropical waters is proved and is seen to be restricted to very regular routes. It is also demonstrated that Fin whales migrate to subtropical waters and both Blues and Fins are shown to return to the same area of the Antarctic, but not so markedly or as regularly as Humpbacks, although definite streams of movement can be recognised. In these two species there is also a spreading movement from one region of the Antarctic to another, but intermingling between the whales of some areas is very slow. Blues are being killed at a faster rate than Fins, and the rate of persecution of distinct streams of whales can reach very high figures.

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Dr. D. S. MacLagan.—Some significant results of recent animal-population studies.

At one time it was presumed that any attempt to formulate principles concerning the attributes and behaviour of animal-populations, was a will-o'-the-wisp pursuit, in virtue of the diversity of living organisms. The discovery that the *growth* of populations can be described by the 'logistic,' or S-shaped curve, has radically altered this point of view ; and indicates that despite important differences between different populations, the basic biology of population-phenomena is applicable to all, whether they be men, mice, or weevils. By means of statistical and experimental analyses, the writer has attempted to evaluate the factors which cause the deceleration in the growth-rate of populations approaching their upper limit, i.e. to account for the shape of the curve of population-growth. It has now been found that even under optimum physical conditions, with abundant food and no deleterious waste products, animal-populations offer an internal resistance to their own growth. As the population-density increases, the factors inhibiting the rate of population-growth become more intensive in their action and tend to come into operation in a definite sequence. The significance of crowding in relation to the epidemiology of animals (including man) is gradually becoming realised. Suffice it to say, that, in virtue of the internal resistance (a complex of factors affecting the actual and potential numbers of the population), populations can inhibit their numerical increase ; and hence, the organism itself imposes the ultimate limit to its own abundance, in the absence of other factors of control. Problems of population are probably the most important ones confronting humanity, and ecologists are contributing their share towards a deeper knowledge of the principles underlying population-phenomena in general.

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Dr. F. Fraser Darling.—Semi-popular lecture on the Atlantic Grey Seal.

The Atlantic or Grey Seal, *Halichoerus gryphus*, is one of the rarer seals of the world. It inhabits the temperate coastal waters of the North Atlantic and is most numerous off the West Coast of Scotland. The remote islet of North Rona, nearly 50 miles north of the Outer Hebrides, is the largest breeding ground. The seals feed on inshore fish about the West Highland Coasts until August, at which time they migrate to the few breeding places. The bulls come ashore first and establish small territories ; calving cows follow in a few days' time. Feeding is abandoned during the weeks the seals are breeding. The calves change coat at 2–3 weeks old and are weaned at this age. Bulls and cows repair to certain rocks near the breeding

grounds to change coat in November and December. The calves are left to find their own way to sea. Territories and nursery grounds on Rona extend to 300 ft. above sea-level, but the nature of the coast line and other environmental factors influence behaviour in this respect. The bull is relatively passive at the breeding grounds and has an average of only five cows in his territory.

Prof. F. W. Rogers Brambell and Mr. H. A. Cole.—The phylogenetic significance of a new preoral ciliary organ found in Enteropneusts.

A detailed comparison of a preoral ciliary organ found in certain Enteropneusta with the wheel-organ of Amphioxus, and the craniate hypophysis, reveals some remarkable similarities, but also some differences. This organ resembles the wheel-organ of Müller in its position in front of the mouth, epidermal character, and general ciliary nature. It resembles in its symmetrical arrangement both the hypophysis of the Craniata, and the hypothetical primitive condition of the homologue of both the preoral pit of Amphioxus and the hypophysis. The preoral ciliary organ differs from the wheel-organ in being separate from, although close to, the proboscis pore, and in the fact that the cells forming it bear tufts of cilia, while those of the wheel-organ each bear a single flagellum. It is thought that the shortening of the preoral region in Amphioxus, in comparison with Enteropneusta, may be responsible for the close association of the wheel-organ with Hatschek's pit, while the flagellation of the individual cells of the wheel-organ is probably a secondary development, since flagellate epithelium is unknown among the Craniata, while ciliated cells are of frequent occurrence. A close examination of these differences therefore tends to strengthen the belief that the wheel-organ of Amphioxus, the preoral ciliary organ of the Enteropneusta, and the hypophysis of the Craniata, are homologous structures.

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Mr. R. S. Hawes.—Notes on the eye and light reactions of Proteus.

THE SCOPE AND LIMITATIONS OF PHYSICAL ANTHROPOLOGY

ADDRESS TO SECTION H.—ANTHROPOLOGY

By Prof. W. E. LE GROS CLARK, F.R.S.

PRESIDENT OF THE SECTION.

For many years now it has been established beyond doubt that Man is one of the terminal products of organic evolution, and that he achieved his humanity at a comparatively recent date in geological time. He was an animal dominated by the primitive instincts of the wild creature before he was a Man capable of controlling his own destiny by his intellect. He must be studied

as an animal before he can be properly appreciated and appraised as a human being. The subject which is concerned with the study of Man from this point of view is Physical Anthropology, and it may perhaps be claimed that, of all the subdivisions of anthropological science, Physical Anthropology is the most fundamental, since it concerns itself with the physical nature of Man, and the physical nature of Man underlies ultimately all those intellectual, æsthetic, and social activities which supply the material for other branches of anthropological study.

This address provides an opportunity of reviewing briefly the present position to which Physical Anthropology has brought us in the study of the origin of Man in the past, of his differentiation into the variety of races or ethnic groups which are dispersed over the world to-day, and of his potentialities for the future. There are several reasons why it is desirable to make such a survey. Among these is the fact that the subject of anthropology spreads its domain over unusually wide fields of scientific enquiry, so that its problems demand the attention of specialists of very different training and experience. For the anthropologist, indeed, Man is the focal point on which the activities of many departments of science converge, and this necessarily brings with it a difficulty—the difficulty of preserving the coherence of the subject of anthropology as a separate and integrated department of knowledge. For it is becoming increasingly impossible for the representatives of the different branches of anthropology to maintain intelligent contact with each other, and it is certainly becoming more and more difficult for each representative to judge for himself of the validity of the evidence which is presented in branches other than his own. Consequently, it is a matter of some importance that the nature of this evidence should be reviewed from time to time by those competent to do so, in order that conclusions and interpretations advanced by a specialist in one branch can be assessed at their true worth by specialists in other branches.

The Zoological Position of Man.

One of the major problems in Physical Anthropology is to determine the relation of Man to other groups of animals in the Order Primates, and to trace the various phases of evolutionary development which led to his emergence from generalised Primate ancestors. Enquiries of this kind involve several methods of research. Comparative anatomy, in the first place, can supply a great deal of information regarding systematic affinities, and this may be further supplemented by studies in comparative embryology and comparative physiology. The results of the extensive researches of this kind which have been carried out in recent years have served to substantiate in general the views held by most anthropologists, namely, that Man has relatively close systematic affinities with the anthropoid apes ; in other words, that the human phylum was derived (in the evolutionary sense) from a common ancestral group which also gave rise to the modern anthropoid apes. In a number of details, however, a thorough enquiry into morphological comparisons has led to certain modifications of this generally accepted thesis. The reason for this is that comparative anatomists and palæontologists have come to realise that *parallelism* has played by no means an insignificant part in

organic evolution. Now this conception considerably complicates phylogenetic problems, for it makes it necessary to distinguish between morphological similarities betokening real genetic relationship and those which are secondarily acquired as the result of convergence, that is, of evolutionary differentiation which may have occurred in the same direction in different groups independently. The phenomenon of parallelism has been demonstrated in many different phylogenetic series, and it is a factor which also demands the closest consideration in the study of Primate evolution.

It may be pointed out that some degree of evolutionary parallelism is naturally to be anticipated, since it must be deemed likely that descendants of a common ancestor will be endowed with similar evolutionary potentialities, and will in the course of time tend to develop in the same general direction unless this is prevented by adverse environmental influences. The acceptance of this thesis inevitably leads to the recognition that anatomical similarity is not by itself necessarily indicative of a correspondingly close genetic affinity. Resemblance is no proof of relationship. Thus a possible fallacy is exposed which in the past has undoubtedly been responsible for hasty conclusions regarding systematic relationships. Indeed, many examples could be cited of cases in which structural similarities were taken at first to indicate close genetic relationship but which later proved to be merely an expression of parallelism. It is now realised that a mere numerical computation of anatomical resemblances cannot provide a sound foundation for estimating degrees of affinity. Genetic affinity can only be assessed on comparative anatomical data by the proper evaluation of anatomical characters with due regard to their taxonomic importance. Let us refer to some specific cases by way of illustration.

In the commonly accepted classifications of the Primates, the lemurs are placed in the lowest grade as a separate sub-order, Lemuroidea. In some respects the lemurs are a good deal more primitive than other Primates, and it has therefore been supposed by many anthropologists that the higher Primates must have passed through a lemuroid phase in their early evolutionary history. This conception was reinforced many years ago by the discovery in Madagascar of certain fossil lemurs which had developed such astonishingly simian characters that some zoologists were led to the view that they represented an actual transition from lemur to monkey. It is now known, however, that the Lemuroidea as a whole became highly specialised in certain features in very early geological times ; from their earliest appearance in Eocene times they followed developmental trends in their dentition, skull and brain which culminated in aberrant specialisations. It is difficult to imagine, therefore, that they could have given rise to the higher Primates in which these specialisations were avoided. As for the extinct monkey-like lemurs of Madagascar, it is now known that true monkeys had already come into existence very much earlier in geological time. In addition to this, a close study of these extinct Madagascan lemurs has shown that the simian traits are superimposed on fundamental lemuroid specialisations which in themselves would probably debar lemurs from further consideration in the ancestry of the higher Primates. It is clear, therefore, that these lemurs took no part in the evolutionary development of the higher Primates. In other words, their simian resemblances must be attributed to evolutionary parallelism.

Another striking example of evolutionary parallelism among the Primates is to be found between the New World and the Old World monkeys. There is evidence to show that these two groups diverged in their phylogenetic history very early in Tertiary times ; indeed, it has been reasonably argued by competent palæontologists that they arose independently from different tarsioid ancestors. Yet a comparison of such existing genera as *Cebus* and *Macaca* reveals many remarkable similarities in the structure of the brain, skull, limbs, etc., similarities which presumably must have been acquired independently of each other.

However, physical anthropologists are in general more concerned with the affinities of the higher Primates, and particularly with the position of Man himself. If parallelism has been so prominent a factor in the evolution of the lower Primates, how far may it not account for the morphological resemblance of Man to the anthropoid apes ? There is little doubt that, if a numerical computation of anatomical characters were really feasible, of all the anthropoid apes it would be found that the gorilla and the chimpanzee resemble Man most closely. It has been concluded on such grounds that these two are therefore most closely related to him (' related ' in the sense that Man is presumed to have arisen comparatively recently in geological times—perhaps even as late as the Pliocene—from a common ancestral stock which also gave rise to the gorilla and the chimpanzee).

In considering this problem, it must again be emphasised that a mere numerical computation of anatomical characters is of little value in making an assessment of affinities—indeed, it may be positively misleading, since it takes no account of correlations such as those which are related to the mutual interaction of tissues during morphogenesis. Apart from this, however, is there any positive evidence to suggest that the striking resemblances between Man and—for example—the gorilla may have their origin at least partly in parallelism ? There is indeed some evidence that this is the case. Several anatomists have drawn emphatic attention to the structural specialisations which have been developed in the gorilla in evident adaptation to extreme arboreal habits. Among these specialisations may be mentioned the hypertrophy of the upper limbs, the reduction in size of the thumbs, the relative shrinkage of the hind-limbs, and certain distortions of the small bones of the foot which (as first pointed out by Morton [1]) may be attributed to the shifting forwards of the centre of gravity of the body in association with the great development of the shoulders and arms. In contrast with the large anthropoid apes, Man has avoided these aberrant specialisations ; in other words, in this respect he actually retains a more primitive and generalised structure.

It thus appears probable that the human phylum must have diverged from the line of evolution leading to the anthropoid apes at a point in geological time when these arboreal specialisations were yet undeveloped. This conclusion does not depend for its validity on a rigid and unreasonable adherence to the ' law of irreversibility of evolution,' as some anatomists appear to think. There is certainly a good deal of palæontological evidence in favour of this principle, and this evidence may be taken to indicate that a ' positive reversal ' [2] (i.e. the reappearance of a character which has once been lost) is at least a very

[1] D. J. Morton, ' Evolution of the Human Foot,' *Amer. Journ. Phys. Anthr.*, VII (1924).

[2] *Early Forerunners of Man*, p. 12. London, 1934.

rare occurrence in phylogenesis. Nevertheless, the possibility of its occasional occurrence is not precluded.[3]

However, if we accept the palæontological evidence that irreversibility is at least a general feature of evolutionary development, we may quite legitimately infer from comparative anatomical studies that it is extremely improbable that Man was derived from an ancestral stock in which the limbs had become highly specialised for arboreal life. We may go further, and suggest the probability that Man diverged from the anthropoid ape stock at a time when the common ancestors were relatively small and agile animals, that is, before the weight of a heavy body adapted for brachiation in the trees might have led to secondary distortions of the foot skeleton. If this inference is true, it at once becomes clear that many of the Man-like characters of a gorilla (such as the large and well-convoluted brain, and many details of the skeleton) are parallel developments related to the increase in body size, and probably also related to the fact that the gorilloid and human stocks have inherited from some distant common ancestor a common potentiality for evolutionary development along similar lines.

It is interesting to note that, in recent years, detailed and careful comparative anatomical studies have led more and more students to the inevitable conclusion that the evolutionary history of Man and the anthropoid apes has been complicated by the effects of parallelism. There remains no justification, however, for taking the extreme view that these higher Primates are in no way related to each other. Such a conclusion does violence not only to all the evidence of comparative anatomy, but also to the available palæontological evidence. The very fact that parallelism has occurred between Man and the apes indicates that they are *ultimately* derived from a common ancestral stock which endowed them with similar evolutionary potentialities. Moreover, even if it be accepted that the representatives of this ancestral stock could hardly have manifested the aberrant specialisations characteristic of the modern anthropoid apes, it remains reasonably certain that they must have shown in the structure of their brain, skull and dentition, anatomical characters which would demand their inclusion in the zoological category of *Anthropomorpha*. In other words, it remains true to say that Man had a simian ancestry. This relationship is well emphasised in a new classification of Mammals recently put forward by G. G. Simpson,[4] for he includes Man and the anthropoid apes in one superfamily, *Hominoidea*.

The question now arises whether we are likely to gain any more certain knowledge regarding the genetic affinities of Man and the anthropoid apes by further comparative anatomical studies of existing forms. The answer to this is—probably not. There has already been accumulated a great store of information concerning the anatomy of the higher Primates, and on the basis of this material it is possible to draw certain inferences in respect of the probable genetic affinities of one group with another. No doubt there is a great amount of data of this kind still to be recorded by patient investigation, but it

[3] Support for the concept of the irreversibility of evolution has recently come from an unexpected source—biochemistry. See the essay by E. Baldwin, 'Rigidification in Phylogeny,' *Perspectives in Biochemistry*, p. 99. Camb. Univ. Press, 1937.

[4] G. G. Simpson, 'A New Classification of Mammals,' *Bull. Amer. Mus. Nat. Hist.*, LIX, p. 259 (1931).

now seems unlikely that such studies by themselves will clarify further the phylogenetic problem, simply because of the inherent difficulty or impossibility of distinguishing between anatomical resemblances due to a true relationship and those resulting from parallelism. Comparative physiological studies are complicated by the same issue. For example, it has been found that the blood-serum and red corpuscles of the anthropoid apes contain group iso-agglutinins and group iso-agglutinogens which are identical with those of human blood, yet, according to Zuckerman,[5] there is suggestive evidence that Man and the apes evolved their several blood-groups independently. From this kind of evidence, therefore, we reach conclusions similar to those based on morphological data; namely, that these higher Primates possess certain features in common which indicate a community of origin at *some* phase in their evolution, but that many of the resemblances shown by different genera may be the result of evolutionary parallelism. This is perhaps as far as it is possible to get on the evidence of the comparative anatomy and comparative physiology of existing Primates. For further progress in the study of phylogenetic problems, we must in the future rely on the evidence which accumulates from the study of the fossil record.

The Palæontological Evidence of Human Origins.

Fossil primates are but rarely found. Consequently, the physical anthropologist has to exercise considerable patience as he waits for the discovery, year by year, of more of these valuable prehistoric records. Their very rarity, however, compels him to make the most intensive study of every available fossil fragment, and inevitably leads to the danger that he may attempt to compensate for the paucity of factual evidence by speculative argument.

Let us very briefly refer to our present knowledge of the origin of Man in so far as it rests on palæontological evidence. No remains of *Homo sapiens* have yet been discovered in geological deposits antedating the Pleistocene age. It remains very doubtful, indeed, whether any fossil remains of the *Hominidæ* which have hitherto been found can be rightly referred to the Pliocene (in spite of the evidence offered by ' eoliths '). We know that earlier still, during the Miocene, several genera of primitive anthropoid apes (e.g. *Dryopithecus*) were fairly widely distributed over the Old World, and there are good morphological reasons for supposing that some of these genera gave rise by divergent evolution to all the existing anthropoid apes and also to Man himself. The evidence for this, however, rests almost entirely on preserved fragments of jaws and teeth. While some of these retain quite generalised characters, others show structural approximations to the various large apes which live to-day, the gorilla, chimpanzee and orang-utan; on the other hand, certain species of *Dryopithecus* (and allied genera such as *Ramapithecus*) in their dentition betray astonishing similarities to Man. We thus have a suggestive picture in Miocene times of the initial appearance of a number of offshoots of the dryopithecine stock, which seem to have provided the ancestral basis for the development of Man and the modern genera of apes. It appears, indeed, that this splitting up into the several genera of the Hominoidea must have

[5] *Functional Affinities of Man, Monkeys, and Apes.* London, 1933.

occurred quite early in Miocene times, for by the middle of this geological period the characteristic specialisations of the dentition found in the modern apes were already clearly evident in the incipient stages of their development.

Apart from jaws and teeth, one humerus and a femur, no other remains of the *Dryopithecus* stock have come to light. So far as the limb fragments go, they suggest that the limb proportions at this phase of the evolution of the higher Primates were not specialised as they are in modern anthropoid apes. It is particularly disappointing that no other portions of the skull and skeleton have been found. There can be no doubt that they would provide evidence of the utmost value regarding the origin of the *Hominidæ*, and physical anthropologists eagerly await the opportunity of studying this evidence when it does become available.

Between the Miocene genera of anthropoid apes and the earliest fossil record of Man there remains a large gap in the palæontological sequence. The oldest representatives of the *Hominidæ* of which we have any real knowledge are *Pithecanthropus* from Java, and *Sinanthropus* from the early Pleistocene of China. The fact that some anthropologists have classified the remains of these early representatives of Man as two different genera is a good example of the results of the difficulties encountered in the study of rare fossils of this type ; for, since such fossils usually turn up singly, and often at intervals of several years, each one is made the subject of intensive study without the advantage of adequate material for comparison. Consequently, the anthropologist tends to exaggerate in his own mind the significance of small structural differences which, after all, may be merely an expression of interspecific or even of individual variation. This now appears to be certainly the case with *Pithecanthropus* and *Sinanthropus*, for, since the initial discovery of the type specimens, the remains of a number of other individuals have been found which emphasise the wide range of variation in both groups. Indeed, the overlap in variation between the two is quite considerable, and it is clearly desirable that they should both be included, for purposes of classification, in the one genus, *Pithecanthropus*. The range of variation among members of this group may be illustrated by reference to the cranial capacity of adults, which varies from 750 c.c. to 1,200 c.c. Now such a range of variation in the small number of individuals which have been found is very remarkable, for in so ancient a type of Man it can hardly be attributed to the effects of extensive intermixture. The knowledge that this variability does occur should therefore guard anthropologists against making too hasty assumptions on the basis of the study of isolated specimens.[6]

[6] The variability manifested by these early representatives of the *Hominidæ* serves to emphasise the fact that the range of genetic variation in Man is quite exceptional in contrast with lower animals. In other words, Man is distinguished physically from other mammals not only by the possession of certain general anatomical characters, but also by the degree of variability which they show. The extent to which these genetic characters can be modified by environmental influences is also a distinctive feature of Man. This variability undoubtedly has far-reaching implications in the study of all branches of anthropological science. It seems certain, for example, that it has been an important factor in the evolution of human society, for it allowed a wide range in the development of individual abilities, and also provided for the considerable plasticity which is a pre-requisite for the building up of complex types of social organisation. If it is to be supposed that the evolutionary emergence of Man was accompanied by the development of any new biological phenomenon, it is in the degree of human variability that such a phenomenon must be sought.

A remarkable feature of the *Pithecanthropus* group is that while the skull, brain, and dentition showed many primitive and simian traits, the limb-bones were quite similar in every respect to those of *Homo sapiens*. It therefore appears that these early types of mankind had, by the beginning of the Pleistocene, already acquired the shapely limbs of modern Man. This observation obviously has an important bearing on the problem of human antiquity, for it demonstrates that if at such an early geological date the contrast which exists to-day between the limb-structure of Man and that of the anthropoid apes had already been achieved, the point in geological time when the former diverged from the latter must have been correspondingly more remote.

The validity of skeletal evidence in the study of human evolution.—Let us now consider the precise nature and extent of the information regarding the path of human evolution which can be gained from the study of the fossil remains of an extinct type of mankind. Actually, the information is usually rather limited, at least in so far as the study is confined to single, isolated specimens, in contrast to an extensive palæontological series. Certainly it is more limited than some anthropologists would probably be prepared to admit. The physical anthropologist will first compare, detail by detail, the skull, teeth and other skeletal elements of his fossil with those of modern Man and with those of the anthropoid apes. He can then define the degree to which the fossil type preserves primitive and simian characters, and he can in some measure assess its evolutionary status by noting how far it shows a structural approximation to *Homo sapiens*. The question now arises, how far is it possible on purely morphological grounds to assert that a human fossil type is an aberrant side-line of evolution, and not rather a representative of a stock which has an ancestral relationship to *Homo sapiens* ? Undoubtedly, a decision on a problem of this sort is extremely difficult. In an attempt to arrive at such a decision, the anthropologist must take into account the anatomical characters of modern Man, and the manner in which they have come to be variously modified ; he must then do the same for Man's nearest relations, the anthropoid apes ; finally, he must have in mind a general conception of the trend of evolutionary development, that is, from the generalised to the specialised. He can then proceed to hypothecate a common ancestor or prototype from which it is readily comprehensible that the diverse modifications of the existing Hominoidea could have been derived. On the basis of such reasoning, it is legitimate to infer that this common ancestor resembled the modern anthropoid apes in many of its general features. On the other hand it presumably showed none of the specialised characters which the anthropoid apes have evidently acquired since. Therefore, in so far as any fossil human type exhibits characters intermediate in their development between the hypothetical prototype and modern Man, it may be regarded as bearing an ancestral relation to him : but in so far as it shows specialised characters which have been avoided by modern Man, it must be regarded as an aberrant offshoot from the main evolutionary line.

In the absence of a fairly comprehensive fossil record, however, it is rarely possible to arrive at a certain conclusion of this kind, for though the law of irreversibility of evolution may be valid in regard to positive reversals, negative reversals are by no means unknown. That is to say, a specialised character

which has been acquired during evolutionary development may be subsequently lost again. Nevertheless, it is legitimate for the anthropologist to make general inferences on purely morphological evidence, even if these must await final corroboration from other palæontological data. By way of illustration, we may refer to the position of Neanderthal Man in human evolution.

There are several features in which the classical examples of Neanderthal Man (of later Mousterian date) appear more specialised than modern Man, and it is for this reason that many anthropologists have for some time held the opinion that this extreme type can have no place in the direct line of descent of *Homo sapiens*. For example, there are the excessive development of the brow-ridges, the peculiar conformation of the molar teeth with their enlarged pulp-cavities and their fused roots, and many characters of the limb-bones. In this particular instance, such inferences (based on indirect morphological evidence) have been confirmed by other palæontological evidence, for we now know that pre-Mousterian Man was much less 'Neanderthaloid' than the later Mousterian types, and more akin in general characters to *Homo sapiens*. It therefore seems certain that modern Man was derived, not from the extreme Neanderthals of later Mousterian, but from more generalised types of earlier date.

It is necessary to emphasise again that the precise position of an extinct type of Man in human phylogenesis can ultimately only be settled by the accumulation of sufficient palæontological evidence, with a sufficient number of well-dated fossil specimens which can be arranged in a graded series. It is also desirable, in dealing with a single fossil skull, to draw continual attention to the dangers of ignoring the possible range of individual variation, and also (perhaps still more important) of ignoring the extraordinary range of variation in quite modern types of Man. There is no doubt that some anthropologists in the past have been led to wholly erroneous conclusions on the basis of such an elementary fallacy. For example, small aberrations in the suture pattern in certain fossil skulls have been held to indicate a divergent line of human evolution simply because they do not conform with the usual pattern found in modern Man. Yet precisely similar aberrations may be found in a small percentage of modern human skulls. The intensive study of single human fossils has also led anthropologists sometimes to discover metrical characters which are presumed to be quite unique simply because no account has been taken of the range of variation in modern Man. Fortunately, the accumulation of biometric data referring to skeletal variation in modern Man has now provided adequate comparative material, and this in future should limit the possibility of *ex cathedra* pronouncements on the significance of a single human fossil being made, where these pronouncements are not supported by objective evidence.

The validity of the evidence of endocranial casts.—The study of endocranial casts has rightly come to be regarded as a very important item in the examination of fossil skulls. There is much to be learnt from them regarding the size, shape and proportions of the brain, and valuable information may also be gained about the pattern of the meningeal vessels and even of some of the surface features of the cerebral hemispheres. Unfortunately, however, this information is somewhat more limited than many anthropologists suppose. The convolutional pattern of the brain does not impress itself on the bones of the human or anthropoid-ape skull with the clarity found in many lower

mammals, and many surface irregularities of a human endocranial cast are caused by quite other factors. The interpretation of some of these irregularities has in many instances depended on the personal attitude of the observer rather than on satisfactory objective evidence. This fact was pointed out many years ago by Symington,[7] and in a recent paper [8] it has been shown in chimpanzees, by a comparison of endocranial casts with the actual corresponding brains, how difficult or even impossible it may be to infer the convolutional pattern from the cast.

Let us refer to one feature on which considerable emphasis has been laid from time to time—the so-called 'simian sulcus' of the brain. This sulcus, which is found in the occipital lobe, is highly characteristic of the brain of anthropoid apes. In *Homo sapiens*, on the other hand, it is usually quite vestigial, though (especially in the brains of primitive races) it may sometimes be well developed and there seems no doubt that somewhere in the ancestry of Man it must have been a normal feature of the brain. Certain grooves on the endocranial casts of fossil types of Man have been accepted by many anthropologists as the impressions of a real simian sulcus, the inference being that in this respect the brain approached that of the anthropoid apes. It may be said at once that such grooves may not in all cases be related to cerebral sulci at all. Apart from this source of error, however, it was pointed out by the late Sir Grafton Elliot Smith [9] that in modern human brains a sulcus may on occasion be developed in the occipital lobe which appears superficially to be identical with a simian sulcus, but which dissection shows to be really another and more recently developed sulcus situated anteriorly to it. Now, if it is impossible in such cases to identify with certainty a simian sulcus in an actual brain, it is obvious that to attempt to do so with only an endocranial cast for evidence is hazardous in the extreme.

It must be frankly admitted that the identification of individual sulci and convolutions on endocranial casts is in most cases not a practical proposition. An exception, however, is sometimes found in the lower and front parts of the frontal lobes, and also in the lower part of the temporal lobe. Here the convolutional pattern may be reproduced fairly distinctly, and even if the impressions of the sulci do not permit of the delineation of known cortical areas, they at least give some welcome information regarding the degree of general complexity of the convolutions in these parts of the cerebral hemispheres.

The validity of skeletal evidence in the study of the individual.—Apart from the consideration of the evolutionary status of a human fossil, the physical anthropologist can learn certain details about the individual whose skeletal remains he is studying. For example, he can estimate the height with a fair degree of accuracy if the long bones of the lower limb are preserved; he can assess its approximate age by referring to the dentition, suture closure, etc.; he can obtain a general idea of the bodily proportions and muscular development; and he can detect the existence of pathological conditions in so far as they

[7] J. Symington, *Journ. Anat.*, L, p. 111 (1916).

[8] W. E. Le Gros Clark, D. M. Cooper and S. Zuckerman, 'The Endocranial Cast of the Chimpanzee,' *Journ. Roy. Anthr. Inst.*, LXVI, p. 249 (1936).

[9] G. Elliot Smith, *The Variations in the Folding of the Visual Cortex in Man.* Mott Memorial Volume, London, 1929.

affect the bones and teeth. Such studies have shown us that the earliest known types of Man were not the large and strong people so often depicted by popular imagination—they were, in fact, by comparison with modern Europeans, rather undersized and narrow-shouldered individuals. Of their habits of life the skeleton provides little evidence. ' Squatting facets ' on the tibia and talus may give a hint of the common posture assumed during rest. On the other hand, the flattening of the shafts of the femur and tibia (platymeria and platycnemia), which in the past have been associated by some anthropologists with activities such as hill-climbing, have now been shown to be probably dependent on a nutritional defect.[10] Contrary to another prevalent conception, also, very little is to be learnt from the anatomy of the teeth about the nature of the diet, except that the degree of attrition bears some relation to the coarseness of the food.

The sex of the individual can often be inferred if sufficient of the skeleton is available for study—particularly the pelvic bones. Even so, however, such a decision may be difficult or impossible. In a study of the Indians of Pecos, Hooton [11] records that of 264 skeletons examined independently for sex determination by himself and the late Prof. Wingate Todd, agreement was reached in only 78 per cent. When the skull alone remains, it must be frankly admitted that it is actually impossible to say with any certainty whether it is male or female, though of course it is possible to draw certain inferences from the massiveness of the bones, the muscular markings, the development of the supra-orbital ridges and mastoid processes, and the size of the teeth. While it is no doubt legitimate to suggest that a certain fossil skull is more *likely* to be of one sex than the other, craniology has not yet advanced to the stage which allows more than a very tentative suggestion of this kind. Indeed, Hooton is clearly right when he says that ' every anthropologist, unless he deceives himself, must recognise that many of his decisions as to sex are questionable.'

It must be admitted that the inferences regarding the living individual, which can legitimately be drawn from the study of the skeleton, are less extensive than some anthropologists have supposed. We know now, for example, that the structure and form of the mandible give no real indication regarding the power of articulate speech, that the asymmetry of the skull is not related to right- or left-handedness, and that it is not possible to assess the intelligence of a normal human individual by reference to the cranial capacity. It is unfortunate, also, that the skeleton gives no indication of external features such as skin colour, hair colour and hair form, on which so much reliance is placed in the differentiation of modern racial types.

The Physical Anthropology of Race.

Mankind to-day is split up into a large number of ethnic groups scattered over different geographical areas of the world, and these have been classified, on the basis of somatic characters, in a system of primary races and secondary races. There is now a general agreement among anthropologists on the definition of the main, primary races, for these subdivisions are each characterised by well-marked physical traits which are based on genic differences, and

[10] L. H. Dudley Buxton, ' Platymeria and Platycnemia,' *Journ. Anat.*, LXXIII, p. 31 (1938).
[11] E. A. Hooton, *Indians of Pecos*. Yale University Press, 1930.

many of which are also known to follow the ordinary laws of Mendelian inheritance. The classification of the secondary races of mankind, on the other hand, is subject to considerable controversy, since it is often difficult or impossible to define them on the basis of clear-cut criteria. There are several reasons for this. In the first place, free migrations and intermixture between different groups have been so prevalent from the earliest times in human history that it now becomes almost impossible to find any pure races left in the world. Again, as Huxley has pointed out, *Homo sapiens* in the later stages of his evolution has been subject to what is termed 'reticulate' evolution. Whereas differentiation of the various forms of life has usually taken place by a process of divergent evolution, new forms may also occasionally arise by the hybridisation of two originally distinct varieties. In the reticulate evolution of Man, on the other hand, the different ethnic groups have come into existence as the result of a complicated process involving periods of divergent modification alternating with periods of intermixture and hybridisation. Probably as a result of this complication, Man, in comparison with other animal species, shows an extremely wide range of genetic variability. Consequently, the distinction between sub-races can usually only be made by a statistical analysis of physical traits. This applies particularly to the general body proportions, skeletal characters, pigmentation, and serological differences ; and in these features even the primary races may show a considerable overlap.

The validity of taxonomic characters in the study of racial differentiation.—The question now arises as to what characters should be selected for comparative racial studies. Clearly emphasis should be laid primarily on those which are known to depend on genic differences—such as the skin pigmentation, eye colour, and hair form. Many other physical characters on which reliance is often placed are susceptible to environmental influences to a greater or lesser degree, and variations due to such causes may obscure fundamental similarities. Some cranial and facial measurements, for example, and measurements of body proportions, are open to such possibilities of error. There is certainly evidence that the shape of the skull is inherited according to Mendelian principles, but even this character is susceptible in some degree to nutritional and other influences. Again, the nasal index (which forms one of the weapons in the armamentarium of the craniologist) has been shown to be correlated with climatic conditions. There is little doubt that a considerable amount of work requires to be completed on the question of the inheritance of such characters before they can be safely used for the study of racial relationships and racial origins.

It is because of the uncertainty of the sort of evidence commonly employed in anthropometry that the investigation of blood-groups has recently assumed such prominence, for blood-groups have been definitely shown to be related to true genic mutations. Moreover, since the variations in blood-groups seem to be quite unrelated to external environmental factors (i.e. they are non-adaptive characters), they appear to provide ideal criteria for assessing the affinities of the various subdivisions of mankind. In fact, the study of blood-group distribution has provided a good deal of information regarding racial relationships and racial movements ; yet the results have also been rather disappointing. There are two possible reasons for this. In the first place (as Prof. Gates has pointed out), although blood-groups may in themselves

have no selective value as regards survival, they may possibly be genetically linked to some racial character which is selective. More important, however, is the observation that identical blood-groups may appear independently of each other in different parts of the world as the result of parallel mutations. The work of Gates and others, indeed, has demonstrated that such parallel mutations can occur, and may be quite frequent.

The recognition of parallel mutations in human evolution draws attention again to the disturbing factor of parallelism in the problem of assessing affinities. There is no doubt that many morphological studies of human races have been based on the assumption that structural resemblances always betoken genetic affinity, and it is probably true to say that this general thesis is also commonly implied in biometric work. We have noted that evolutionary parallelism can produce remarkable resemblances in widely different genera of the Primates ; it is to be anticipated that in such closely related groups as the different races of modern Man it has played at least an equally important rôle.

The late Dr. Buxton [12] recently drew attention to craniometrical resemblances between certain groups of the Australian native population and certain negroid peoples of Central Africa. This might be taken to indicate a real affinity, possibly having its origin in a contact of the peoples in the distant past. But such an interpretation involves difficulties, whereas these are avoided at once if it be accepted that the resemblance is simply an example of the common phenomenon of parallelism. This is also the most likely explanation of some of the remarkable resemblances which have been noted between pre-Columbian skulls from America and those of modern populations in the Old World.

The study of racial evolution.—The determination of the evolutionary differentiation and the subsequent migrations of human races presents exceptionally difficult problems for the physical anthropologist. A good deal may be learnt on these matters from the study of modern races and their present geographical distribution. Such evidence, however, is bound to be of an indirect nature. More direct evidence has to be sought from the study of skeletal remains from old burial grounds and prehistoric sites, but this involves the difficulty (which is not generally realised) that it is by no means easy, and may often be impossible, to diagnose a racial type from the study of the skeleton alone.

The primary races of mankind are distinctive enough in the flesh, but the contrast between one and another is unfortunately not reflected to anything like the same degree in the bones. Thus, while it may be easy to identify a skull of a negro, an Australian aboriginal, or a European, in individual cases where the racial characters are exceptionally well marked, the variation within the group is in fact so great that skulls of each type may be found which are impossible of racial diagnosis. This difficulty may be illustrated by reference to the well-known skulls from the palæolithic sites of Grimaldi and Chancelade, on the significance of which there has been considerable controversy.

The Grimaldi skulls have by many anthropologists been held to be quite definitely negroid in type, and even now they are commonly accepted as final evidence of the existence of a negroid race in Europe during Aurignacian times. Yet the late Sir Grafton Elliot Smith,[13] from a study of the actual remains,

[12] L. H. Dudley Buxton, ' The " Australoid " and " Negroid " Races,' *Anthropos.*, XXX, p. 291 (1935).

[13] *Essays on the Evolution of Man.* Oxford University Press, 1927.

pronounced categorically that they show no real evidence of negroid affinities, but are simply variants of the Mediterranean race which now inhabits Southern Europe. The Chancelade skull, of Magdalenian age, was stated by the famous anatomist, Testut, to be that of an Eskimo, and this diagnosis has also been accepted by many reputable anthropologists. This conclusion, again, has been vigorously denied by equally distinguished anthropologists who maintain that it is but a variant of the Cromagnon type of *Homo sapiens*. Now, it is probable that there are no racial types in which the skull characters are more distinctive than in Negroes and Eskimos, and yet experts fail to agree when faced with skulls whose claims to these types are in question. If a decision proves so difficult in such cases, it will be realised how much more difficult, or even impossible, it will be to identify by their skeletal remains races with less distinctive characters.

If there are difficulties in the identification of the skeletal remains of the fully differentiated racial types of to-day, these are very much enhanced when attempts are made to detect corresponding racial differences in prehistoric remains in which the characteristic racial traits were much less developed. Yet it is argued by some anthropologists, on the basis of such ancient fossils, that the primary races of mankind had already begun their divergent differentiation as far back as the beginning of Pleistocene times. While there is no inherent improbability in such a thesis, the anatomical evidence on which it is based remains entirely inadequate. The shape of the incisor teeth and the presence of exostoses along the alveolar margin of the mandible, for example, are not sufficient to justify the conclusion that Pekin Man was the forerunner of the Mongolian races to the exclusion of other racial types. There is likewise no distinctive character in the Rhodesian skull which permits the assumption that *Homo rhodesiensis* was a proto-negroid (even though, in some continental museums, restorations of this fossil man are provided with typical negroid features and hair of the usual negroid type).

The limitations of craniology.—The difficulties to which we have referred raise the whole question of the limitations of craniology in the study of racial problems. The wide range of variation in the anatomical characters of the skulls of even a relatively homogeneous population has led to the extensive development of statistical methods for their analysis. Biometricians have perfected the technique of measuring skulls and have also elaborated a number of indices and formulæ for recording metrical differences and degrees of metrical variation. It was at one time hoped that, given a sufficient amount of material, it might be possible by such methods not only to differentiate one racial type from another, but also to assess their mutual relationships. The results of such studies have not, on the whole, been commensurate with the immense labour involved, and it is probably true to say that our knowledge of the affinities and origins of the different races of mankind has advanced but slowly since the introduction of modern methods of craniometrical analysis. Inconclusive results of investigations such as these are perhaps to be anticipated if consideration is given to the fact that the range of genetic variation in Man is probably unique among animals, that the degree of miscegenation in human populations has been very extensive over almost every part of the world from great antiquity, that all the characters of the bony skull, even if they have a genetic basis, are at least to some degree susceptible to environmental

influences, and that it is by no means easy to collect sufficient well-preserved and properly documented skeletal material for statistical study.

In a recent critique Prof. R. A. Fisher [14] has discussed in some detail the limitations of craniometrical methods, and it is impossible to ignore his general conclusions. Prof. Fisher has pointed out the limitations of the 'coefficient of racial likeness' in its application to ethnographic problems, and has also emphasised the misunderstandings to which its application has sometimes led. He argues very convincingly that physical anthropologists might more profitably direct their attention to living populations rather than to dry bones. He emphasises that the variations produced by fleshy tissues are small compared with the metrical differences between individuals, so that the average of any measurement taken on the living from a sample of fifty or a hundred has practically the same precision as the corresponding measurement of the skull; that in the study of the living, the sex, blood-relationships, nationality, language, religion, and social status are known; and that all the material which can be required is already there, available for the physical anthropologist who chooses to take advantage of it rather than to wait for the accidental discovery of some ancient cemetery which may provide him with material which is usually rather unsatisfactory and inadequate.

The Future of Physical Anthropology.

The brief review which has been given of the rôle of physical anthropology in the investigation of racial problems has served to indicate some of the limitations which are imposed upon it by the nature of the material with which it deals. The study of human palæontology will of course continue so long as fresh fossil material is brought to light either by accidental discovery or by systematic excavation. As the fossil record becomes more complete, it will without doubt be possible ultimately to construct an accurately dated palæontological series which will allow the course of human evolution to be followed with some precision. The palæontologist only needs to exercise patience until the evidence he requires is put before him.

Apart from palæontology, however, it may be doubted whether physical anthropology as an historical science is likely to advance our knowledge of racial origins and racial differentiation very much beyond its present state with the techniques now available. As already noted, the reasons for this somewhat pessimistic prognosis include the difficulty of acquiring adequate skeletal material from which the racial composition of populations in the past can be inferred; the frequent impossibility of identifying racial types by the examination of skeletal material only; the fallacy which may be involved in the assumption that certain craniometrical similarities necessarily indicate a true genetic affinity; and the difficulty of eliminating the effects of environmental influences in modifying physical characters which otherwise have a genetic basis.

In spite of these great technical difficulties, it is certainly desirable that biometric methods should continue to be applied to material which is available, if only to complete a base-line of knowledge from which further advances in

[14] R. A. Fisher, 'The Coefficient of Racial Likeness and the Future of Craniometry,' *Journ. Roy. Anthr. Inst.*, LXVI, p. 57 (1936).

physical anthropology may be made in other directions. It is important, however, that physical anthropologists should be fully aware of the limitations imposed upon them by the nature of their material, and that they should have a clear idea of the sort of knowledge which it is possible to acquire by the application of their methods. A very valuable aspect of the study of present and past populations from the historical point of view by the rigid application of biometric technique is that it permits the testing of the popular conceptions so commonly held to-day regarding the equivalence of race and nationality. No one will doubt the need for the clarification of such ideas. The physical anthropologist, indeed, has an important duty to fulfil in the discussion of modern social problems, by providing objective evidence to show whether there is any truth at all in the tenet that ' nation ' and ' race ' in Europe are in any instance comparable terms. Such studies as have been made on this question have hitherto led in general to negative results. Most anthropologists will agree that the nations of the political world to-day are the product of the fusion of a number of heterogeneous racial components, and that they each maintain a coherence, not by virtue of blood-relationship, but because of common language, customs, traditions and education. Statistical surveys of characters such as hair and eye colour, head shape, blood-grouping, and so forth, have demonstrated that their distribution bears no close relation to political boundaries.

We have now to consider along what lines physical anthropology is likely to show its main advance in the future. Broadly speaking, it may be suggested that its research will be almost entirely directed to the study of *living* populations, particularly in regard to problems of human genetics, the relation of physical characters to the environment, the study of growth processes, and the study of comparative racial physiology. In other words, the physical anthropologist, if he is to justify his subject as a separate scientific discipline with its own special problems and its own technical methods, must be primarily a field-worker. Many biological sciences have passed or are now passing through what may be termed the ' museum stage ' of their development. This stage involves the collection of material in the laboratory, its detailed examination and classification, and the interpretation of the facts which it presents in the form of general hypotheses. Such studies (which are, of course, essential preliminaries) must later give way to experimental methods and to direct observation in the field, for this is the only way in which general hypotheses can ultimately be confirmed and established. The science of physical anthropology is passing through similar phases. To complete its natural metamorphosis, it should now be emerging from the museum stage and developing along experimental lines or along the lines of observation in the field.

In so far as history can be said to provide a basis for prognostication, physical anthropology as an historical science has a considerable practical significance. The study of the bodily changes which Man has undergone in the past gives a clue to the nature and extent of the changes which may be anticipated in the future. *But what is far more important for the same purpose is the study of Man as he is to-day.* Sociological problems are becoming more and more forced on our attention which demand for their solution a conscious control of processes which have hitherto been left to chance. The improve-

ment of health and physique and their relation to nutritional and climatic factors, the effects on physical type of the redistribution of the populations of the world, the results of the hybridisation of different racial types, the relation of changes in the reproductive rate to human variability and the composition of regional populations, all these are practical problems which can be approached systematically and scientifically only if we have adequate data regarding the physical nature of Man in the conditions under which he now lives. It is remarkable that we still lack this essential knowledge. In our own country, for example, we have no proper records which show the variability of different sections of the population living under different nutritional conditions and in different environments. Still less have we any real knowledge of the potentialities for growth and development of native populations living under optimal conditions of nutrition and hygiene. Yet a study of the normal variability of Man to-day, and of his bodily reactions to environmental influences, must clearly be a necessary basis for any assessment of changes which are to be anticipated in the future. Let us note briefly the lines along which physical anthropologists may most profitably seek for this information.

Human genetics.—The study of human genetics offers practical problems of considerable urgency, for no one doubts that the mode of transmission of hereditary defects, which may be manifested in structural abnormalities, metabolic disorders, or susceptibility to diseases of one kind or another, should be elucidated in all possible detail. The problems of human heredity form the basis of the whole science and practice of eugenics, and the eugenist requires to have all the data of human heredity at his disposal if he is to exert any conscious control over the destiny of mankind in the future. It is already well known that certain physical characters owe their origin to simple gene differences, and their mode of inheritance is easy to follow on ordinary Mendelian principles. It is also known that other characters have a much more complicated heredity, for they are dependent on the interaction of multiple genes. Such are stature and skin pigmentation. For the purpose of practical eugenics, it is necessary that all those mental and physical characters of Man which are judged to be significant for human welfare should be fully analysed to determine, in the first place, whether they have a genetic basis at all, and, secondly, what may be the nature of the genetic differences on which contrasting characters depend. Only on the basis of such knowledge is it possible to foresee what may be the effects of selection applied to such characters.

The field of human genetics offers unusual opportunities to the physical anthropologist for applying his own particular methods of enquiry, for the reason that the study of heredity in Man cannot be pursued by the direct experimental methods employed for the study of animal genetics. Statistical methods are necessary for determining the frequency and distribution of the characters under investigation ; different groups of the population must be studied under different conditions ; pedigrees require to be followed and analysed (a field of work sometimes spoken of as 'family anthropology'), and advantage must be taken of the opportunities offered by the phenomenon of twinning.

Apart from the practical significance of human genetics in relation to the health and progress of mankind, this study has also a direct relation to the more academic problems of the anthropologist. Physical anthropologists

have on several occasions been criticised for employing as criteria in their studies of racial affinities physical characters whose genetic basis is unknown. No doubt such criticism is often justified, for it is clear that only those characters which are the expression of genic differences have any validity in taxonomic problems. There is evidence that the shape of the head is certainly in part determined by heredity, but there is also evidence that it can be modified by post-natal influences. Similarly, it is well recognised that the height of an individual is closely correlated with nutrition, but it is known that it also depends partly on heredity. The relative importance of genetic and environmental factors must ultimately be determined for all such characters as these.

The question of the possible linkage of phenotypic characters is another problem of human genetics which demands intensive investigation, since this phenomenon may permit the recognition of latent defects in cases where they are linked with a physical trait detectable by superficial observation or appropriate measurement. The possible relation of physique to susceptibility to disease is particularly important. It is commonly supposed that a relation of this kind does in fact exist. Physical types, such as those termed 'asthenic,' 'pyknic,' and 'athletic,' have been defined, each with their particular advantages and weaknesses, but, so far, the evidence in favour of such a sharp classification is equivocal, and the same doubt still applies to the supposition that certain racial types are particularly susceptible to infections of one kind or another. For example, there is a current belief that the Negro, as the result of an inherited predisposition, is specially liable to tuberculosis, and that certain types of racial miscegenation likewise lower the resistance to such diseases. Yet in a recent and careful survey by Williams and Applewhite,[15] the conclusion is reached that there is little if any difference between the White and the Negro in resistance to tuberculosis (given equal opportunities for medical treatment), nor do miscegenetic types of the Negro really show a greater incidence of tuberculosis.

The possibility of a genetic linkage of characters also raises the question how far inherited physical traits may be related to an inherited mental disposition. It is common enough, in text-books on anthropology, to find different varieties of temperament assigned to different racial types. For instance, it is stated in a recent comprehensive work on human heredity [16] (by Dr. Lenz, professor of racial hygiene in the University of Munich) that the Mediterranean race (of which, in Europe, the southern Italians are perhaps the best representatives) is volatile and frivolous in temperament, has less sense of truth and honour than the Nordic, and, in respect of rational endowment and character, occupies an intermediate position between the Nordic and the Negro. The Nordic race, on the other hand, is supposed to be endowed with creative energy, with a vigorous imagination, high intelligence, and an unusual degree of self-control.

In spite of statements such as these, the evidence for their truth is remarkably unsatisfactory, and certainly a great deal of careful work must be

[15] G. D. Williams and J. D. Applewhite, 'Tuberculosis in the Negroes of Georgia,' *Amer. Journ. of Hygiene*, XXIX, No. 2, p. 61 (1939).

[16] E. Baur, E. Fischer and F. Lenz, *Human Heredity*. George Allen & Unwin, Ltd., London, 1931.

accomplished before they can be accepted. Some years ago, a pamphlet by Prof. Zollschan was published in which questions were raised regarding the significance of the racial factor as a basis in cultural development. These questions still await answers based on satisfactory evidence.

A problem of a similar kind concerns the so-called 'criminal type.' Evidence for the existence of a 'criminal type' has been sought by anthropologists, the suggestion being that inherent criminal tendencies may be associated with specific physical traits. For many years now this conception has been abandoned. Lately, however, it has once more been resuscitated, and the statement has been made that it is possible to recognise slight statistical differences between the criminal and non-criminal sections of the same populations. Whether this conclusion will ultimately withstand the scrutiny of critical statisticians remains to be seen. It is obviously an extremely difficult matter to eliminate irrelevant factors in an investigation of this kind, and in any case the statistical differences which have been reported appear to be so small as almost to be negligible for practical purposes. The demonstration of a 'criminal type,' however, even if this can only be accomplished statistically, is important in so far as it suggests the possibility that criminal tendencies may depend on genetic factors. Such a conclusion is in fact indicated by the study of identical twins, for it has already been found that criminal tendencies in one of a pair is accompanied in a relatively high proportion of cases by similar tendencies in the other.

Physique and nutrition.—The problems of human genetics and the supposed association of mental traits with demonstrable physical characters are complicated by the growing recognition during recent years that nutrition plays a highly important part in determining the physical variations seen in different races and in different individuals. It is unnecessary to state that a broad relation between nutrition and physique has always been accepted by anthropologists. Stature, weight, chest-dimensions, and so forth, can all be correlated with nutrition. But the suggestion is now put forward by competent dieticians that the effects of malnutrition may be much more extensive, not only as causal agents underlying many types of variation in physical characters, but also in determining susceptibility to different types of infection. If this is true (as it undoubtedly appears to be) it clearly demands the serious attention of physical anthropologists.

The relation of different racial types of physique to diet was first demonstrated by the experimental work of Sir Robert McCarrison.[17] Working among the native races of India, he observed that there appears to be a definite correlation between physical type and the presence or absence of certain food factors in the diet to which each race is accustomed. In order to test this observation he carried out a series of experiments in which different groups of white rats were fed on equivalent diets, and he found that, in their growth, physique and general health, each group of rats paralleled quite closely the corresponding racial types. This pioneer work has led to a great deal of important research along similar lines, both among native populations in the colonies and in the population of this country, and it has opened up practical issues of considerable importance.

[17] R. McCarrison, 'Nutrition and National Health,' Cantor Lectures, Royal Society of Arts, Adelphi, London, 1936.

In this country, indeed, evidence has been put forward which suggests that malnutrition may be far more extensive in the lower economic levels of society than has hitherto been suspected. Clinical and anthropometric comparisons of the children of relatively wealthy parents with those of poor parents have demonstrated a marked contrast in physique, general health, and susceptibility to infections. There is evidence, for instance, that the infantile mortality from respiratory infections is considerably higher in the poor districts of large towns than in the residential areas of the richer sections of the population, and there is also evidence that the predisposition to respiratory infections is related to undernourishment. Moreover, direct experiments (although of a limited nature) have been carried out on human material in which the effects of different diets on growing children have been recorded. Perhaps the best known example of such an experiment is that carried out by Corry Mann [18] on a village colony for boys. He found that, in a group of boys who received additional milk in their daily diet, the average height increase over a period of two years was over $1\frac{1}{2}$ inches more than that in a group fed on a basic diet only.

It will not be doubted that, if there is indeed widespread malnutrition, it is a matter of national interest that it should be corrected as soon as possible. But an essential preliminary to any large-scale plan of action is to collect precise information regarding the extent, distribution, and degree of undernourishment. Here is a problem in the solution of which the physical anthropologist should play a predominant part. He has at least the experience and technique which will enable him to seek an answer to one of the most urgent preliminary questions—by what somatometric method which is both reliable and convenient of application is it possible to assess nutritional status?

It is perhaps a matter for surprise that in this country we still have no adequate standard of what may properly be called *normal* physique, as a basis for comparison when seeking for evidence of malnutrition. This is partly due to the fact that available anthropometric data apply to mixed populations from different parts of the country in which no attempt has been made by careful clinical examination to eliminate those individuals who may be undernourished, or otherwise unfit physically. It is also a fact that the physical standard is by no means fixed and unchanging. There is evidence, for example, that the average height of the population, not only in this country but elsewhere, is rising rather rapidly, and it has been recently estimated that this increase may be as much as one centimetre in every $12\frac{1}{2}$ years.[19] It is possible that this increase is directly referable to improved nutrition, though there are some reasons for supposing that this explanation may not be completely adequate. It remains conceivable that it may possibly represent a definite orthogenetic trend in human evolution which is manifesting itself in statistical analysis.[20]

In order to obtain a basic standard of physique (or series of standards) for comparative studies, it is in the first place necessary to carry out a complete

[18] H. C. Corry Mann, 'Diets for Boys during School Age,' *Med. Research Council Report*, 1926.

[19] G. T. Bowles, *New Types of Old Americans at Harvard.* Harvard University Press, 1932.

[20] The change in stature will undoubtedly be reflected in other somatic measurements. Thus, there is known to be a correlation between the length of the head and the height of the body.

survey of the country by the systematic examination of samples of the population from different districts. Such a survey would require the close collaboration of physical anthropologists with clinicians, Medical Officers of Health, dieticians, and social workers, in order to attempt a correlation between physical development and the normal healthy condition of body and mind, and, if possible, to relate this also to the social conditions of life. In fact, an attempt should be made to extend the health surveys which have been recently carried out in this and a number of other countries, the aim of which has been to correlate also the clinical assessment of nutritional status with anthropometric observations.

On the basis of such an investigation it may eventually be possible to find some relatively simple formula by reference to which the nutritional status of any local section of the population can be rapidly and easily assessed. At least, it can be said that without some method of this sort it will hardly be possible to remedy the malnutrition which is believed by some authorities to be even now causing serious damage to the health of our population.

In a recent publication Prof. Bigwood (of the University of Brussels) has summarised the various somatometric indices which have from time to time been contrived as a basis for the assessment of nutritional status.[21] Examples of these are Röhrer's index, in which the state of nutrition $= \frac{P \times 100}{H^3}$, when P is the weight in grammes and H is the height in centimetres ; von Pirquet's index, $\frac{\sqrt[3]{\text{Weight} \times 10}}{\text{Sitting Height}}$, in which nutrition is assessed as inadequate when the ratio falls below 0·945 ; or Franzen's A.C.H. index, which takes account of the arm girth, chest depth, and hip width. All these indices have been subjected to criticism, either because they require trained observers to make the necessary measurements, or because the indices in each case require to be carefully interpreted with discernment. Yet it becomes apparent from a consideration of the work which has been already completed on their application that they can yield information of practical value in regard to different groups of the population, even if their application to individual cases is not feasible. Even in regard to individuals, however, these somatometric indices are likely to be of considerable practical use if they are applied at intervals during the growth stage in the periodical examination of children, for they may give a clear indication of improvement or otherwise in nutritional status. It is rather a matter now of deciding which index is likely to prove the most useful, and whether it requires any modification in its application to the different sections of the population of this country.

The A.C.H. index [22] seems at first sight to offer considerable possibilities, since it was devised to take account of the general build of the individual and to eliminate errors due to the normal variations in the weight-height-age ratio. The authors of this index recommend that, for general purposes, the scale should be set so that approximately 10 per cent. of any sample group

[21] E. J. Bigwood, ' Guiding Principles for Studies on the Nutrition of Populations,' League of Nations Technical Commission on Nutrition. Geneva, 1939.

[22] R. Franzen and G. T. Palmer, ' The A.C.H. Index of Nutritional Status,' American Child Health Association, New York, 1934. See also R. Franzen, ' Physical Measures of Growth and Nutrition,' American Child Health Association, New York, 1929.

are selected. They claim that, in their experience, about 60 per cent. of such a selection are cases of extreme physical defects, and over 80 per cent. either extreme defects or bordering on extreme defects. They claim, also, that even if the application of the index misses some defective individuals, it is yet more effective than the more commonly used weight for height and age method. Indeed, it is stated that, while the A.C.H. index selects three-fifths of badly defective children, the weight-height-age ratio only selects about one-fifth.

In a recent statistical study of the health and physique of school-children in this country by Huws Jones,[23] rather different results have been obtained. This investigator concludes that indices involving chest and hip measurements do not show any particular advantages over those based on weight and height alone in selecting children who are judged clinically to be under-nourished. For the assessment of nutritional status he prefers to use Tuxford's index, that is (Wt/Ht) × (381 — age in months)/54. This index gives a 'nutrition quotient' which is about 1,000 for average children. One of the most interesting points arising from this study is the question of the validity of clinical methods of assessing nutrition, for it is shown that different physicians may disagree considerably in their estimate of the physique of the same children, and the same physician may also show considerable variation in his estimate of the same children examined at different times. In regard to the Tuxford index, Huws Jones concludes that 'on the average, the experienced School Medical Officer picks out two-thirds, and the index three-quarters, of the boys assessed subnormal by two or more doctors. For this purpose, no doctor is greatly superior to the index, but the index is twice as effective as some doctors.'

It appears from these results that, if we are to obtain a really adequate somatometric index of malnutrition, some method of nutritional assessment more objective than clinical observation must be employed with which to equate physical measurements. A number of physiological tests have been suggested for this purpose. For example, in the case of Vitamin A it is possible to detect latent hypovitaminosis by testing for delay in the dark-adaptation of the retina ; Vitamin C deficiency may be detected by urine analysis or by testing the fragility of the blood-capillaries ; or Vitamin D deficiency by estimating the phosphatase content of the blood. Similarly, a deficiency of iron may reflect itself in slight degrees of anæmia which can be detected by estimating the hæmoglobin concentration of the blood. Other tests which demand consideration include the dynamometric estimate of muscular strength and fatiguability, estimates of vital capacity, the radiographic examination of bone-growth, and so forth.

It cannot be doubted that a great deal of research requires to be completed before the problem of assessing nutritional status is finally solved, nor is there any need to emphasise further the importance of finding some practicable formula by which such an assessment can be made. The whole problem is considerably complicated by the fact that in a population such as we have in this country the intermixture of racial elements introduces a physical variability which may in some cases tend to obscure variations related to malnutrition. This is one of the reasons for urging that physical anthropologists should

[23] R. Huws Jones, 'Physical Indices and Clinical Assessments of the Nutrition of School Children,' *Journ. Roy. Statist. Soc.*, CI, Part I (1938).

take part in a general survey of the physique of this country with a view to establishing a sound basis for comparative nutritional studies. Physical standards will naturally vary from one part of the country to another in relation to the predominance of different racial elements, and it will no doubt be ultimately necessary to establish regional standards in the application of the somatometric index which is judged by experience to be the most reliable.

Observations on the relation of nutrition to physique, capacity for work, and susceptibility to disease are also waiting to be carried out among native peoples in many parts of the world. Some excellent work along these lines has been started in India, Africa, and also in China, where information has been collected regarding the composition of the diet of different sections of the native population.[24] Here the field anthropologist must necessarily give his aid, since he is in the best position to obtain a detailed record of the food elements of the diet which are ordinarily obtainable at different seasons, to study the local customs in the preparation of the food for consumption, and also to collect samples of the various foodstuffs for analytical study by the biochemist. It has already become evident from such observations that in some cases the native diet is hopelessly deficient in certain essential food elements which are necessary for the development of a normal physique and for the maintenance of health. The elucidation of such defects in the diet must surely in the future be a powerful factor for success in colonial administration.

To carry out nutritional surveys in native populations, the physical anthropologist will also require to examine the somatometric indices which have been worked out by reference to European peoples, for they will probably need modification to adapt them to different types. Such a study has already been made (for example) on the Chinese by Stevenson,[25] in the application of von Pirquet's index, and as a result it has been shown that while an index value of 95 is the average mean for most occidental groups, a value of 90 more nearly approaches the racial norm for the Chinese.

The fields of research to which we have drawn attention serve once more to emphasise the fact that the physical anthropologist of the future must be essentially a field-worker if he is going to develop his subject along progressive lines. He must also be a man of sound biological training if he is to acquire a real insight into the problems which are set for him. Some of these problems have a very intimate relation to human happiness and human suffering, and their investigation is a matter of urgency. It is opportune, therefore, that the

[24] See, for example, J. B. Orr and J. L. Gilks, 'The Physique of Two African Tribes,' *Med. Res. Council.*, H.M. Stationery Office, 1931.

R. Firth, 'The Sociological Study of Native Diet,' *Africa*, VII (1934).

A. I. Richards and E. M. Widdowson, 'A Dietary Study of Native Diet,' *Africa*, IX (1936).

L. Nicholls, 'A Nutritional Survey of the Poorer Classes of Ceylon,' *Ceylon Journ. Sci.*, Section D, IV, p. 1 (1936).

W. R. Aykroyd, 'The Nutrition Value of Indian Foods,' *Health Bull.* No. 23, Government of India Press, 1937.

D. Das Mitra, 'A Study of the Diet of the Bengali Hindus,' *Indian Med. Gaz.*, LXXIV, p. 226 (1939).

G. P. L. Miles, 'Rapid Approximations in the Computation of Diet in the Field,' *Man*, May 1938.

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[25] P. H. Stevenson, 'Interrelation of Biometric and Clinical Methods in the Appraisal of Nutritional Status,' *Chinese Med. Journ*, XLVIII, p. 1295 (1934).

methods and technique which have been elaborated by physical anthropologists in the study of human variation in the past should now be directed to their solution.

The science of physical anthropology has contributed much to the study of the past history of the human species. By the study of modern populations it has a still more important function to fulfil, the accumulation of data on the basis of which it will be possible in some measure to control the destiny of mankind in the future.

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SECTION H.—ANTHROPOLOGY

COMMUNICATIONS

Mr. A. L. Armstrong.—New discoveries at Grimes Graves.

Discovery of a figurine of the earth mother and other cult objects associated with ritual, at Pit 15, Grimes Graves, Norfolk.

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Miss C. Fell.—Connections between the Lake District and Ireland during the Bronze Age.

Dr. P. Bosch-Gimpera.—Types and chronology of beakers in Spain.

In Spain, beakers belong to three different periods, corresponding to their type sequence.

(1) Classical style (Ciempozuelos-Alcores-Palmella and lower stratum of Somaén) seems only peninsular and exclusive of central and Portuguese cultures. (2) Evolved types even with most fundamental patterns in less pure interpretation (second stratum of Somaén) begin expansion through contemporary Catalonian cultures (Cartanyá, Salamó, and upper stratum of Pany) and Pyrenean megalithic Ib, reaching Rhineland and Central Europe, also Nordic late Gang-graber. (3) Most evolved types and introduction of cord patterns appear in late eneolithic stages of Almeria (Los Millares, contemporary to Alcalar), Pyrenean II, German Schnurzonenbecher, Nordic Steinkistengräber, also Brittany and from there Ireland, British B-beakers.

Degenerate types on the Rhine, contemporary with German Adlerberg and Vor-aunjetitz, belong to the same period as late Dutch beakers, equivalent to British A-beakers. To this period correspond Irish lunulæ and Spanish pre-Argaric. In next period (continental Aunjetitz and El-Argar) beakers exist only in Britain in most evolved forms.

* * *

Dr. E. Estyn Evans.—Lyles Hill, an Irish hill-site of the Megalithic period.

This paper reviews the results of two seasons' excavation work on a site in Co. Antrim which was discovered from the air some years ago. The bare hill-top (753 ft.) is crowned by a circular cairn which had been built from the débris of occupation sites and yielded a vast assemblage of sherds and lithic material. The latter is mostly flint but includes also polished tools of a well-known north Antrim igneous rock. Four pendants of greenstone, believed to be derived from a non-Irish source, were also recovered. Pottery is exclusively round-bottomed and includes handled forms. At high levels and in secondary cist burials, food-vessels and an encrusted urn were found. The primary burial, in a small closed chamber, had been rifled. A megalithic kerb includes a vestigial entrance with decorated sill-stone. The hill-top is surrounded by a contour earthwork, 3 ft. high and 30 ft. wide, composed of earth and boulders and enclosing a space 950 ft. by 700 ft. It is contemporary with the cairn and occupation sites within.

* * *

Prof. E. O. James.—Primitive cults in the religion of the Old Testament.

While the most ancient documents in Hebrew literature are derived from literary sources which cannot be dated earlier than the ninth, or possibly the tenth century B.C., traces of primitive cults survive in the recorded beliefs and customs which belong to ages prior to the time of Moses and the documented periods. By a comparative study of the material it is possible to determine the nature and significance of pre-Yahwistic practices which the Hebrews and their ancestors held in common with Semitic peoples generally. The cults brought under review include lunar and pastoral festivals, fertility rites and sanctuaries, treatment of the dead, sacred animals, the divine kingship and the Annual Festival.

* * *

Miss I. F. Grant.—The human interest of exhibits in a Highland folk-collection.

1. Reasons for urgent importance of making Folk Collections :
   - (*a*) The material is vanishing rapidly.
   - (*b*) The living traditions attached to the objects can still be gathered.
   - (*c*) Such collections are deeply appreciated by a great variety of visitors, such as old country folk, teachers, children, modern workers in similar processes, and people whose ideas of the past are abstract, romantic or picturesque.

2. The value of many objects in a folk collection does not depend upon their beauty, their monetary value, their association with historic people, their age, sometimes even their rarity. They are worth collecting because they illustrate the manners and customs, the economic conditions, the folk culture of our own ancestors.

In this age of specialisation it is most important that folk collections should be arranged in such a way as to bring this home to the visitors. The author describes how a few exhibits in her own collection (probably similar to those to be found in most other collections) illustrate in a unique way various aspects of the Highlands in the past, e.g. :

History (wool-winder, knives).
Economic conditions (wooden plough, mended hoe, salting keg, wooden slabhraidh).
Effects of environment (types of lighting apparatus, grass and basket furniture).
Variations racial ? (distribution of types of flail).
Manners and Customs (types of chairs and stools, home-made musical instruments).
Folklore (slabhraidh, hobble, position of fire).
Working ways (examples of implements from textile section).
Versatility (summary of tools and home-craft work found in the typical home).

Prof. W. J. Entwistle.—Ballads and tunes which travel.

Mrs. Catriona Mackintosh.—Hebridean music ; pre-Christian myths and legends in song.

In the Hebrides, fragments of music, prechristian—almost prehistoric—have been handed down orally by cultured bardic families. What we owe to the general folk of the Isles is not the invention, but the appreciation and preservation of the traditional airs. The three necessities of life, according to ancient runes and vows, were food, drink and music. The earliest theories of the beginnings of music are highly pictorial and imaginative, and reveal a distinct oriental contact.

A wealth of myth and legend from Fionn and the Fayne—Celtic parallel of King Arthur and his Knights—has been kept vigorous all down the ages, perhaps because they appeal so intensely to human nature—Deirdre for beauty and sorrow, Cuchullan and his son for tragedy, Oscar for bravery, Aillte for charm, and Maeve for jealousy and cruelty. Our labour lilts, too, are fundamental and intensely racial, and the very tyranny of their rhythm will keep them alive. Examples of all these types will be sung and accompanied on the clarsach.

* * *

Dr. A. O. Anderson.—Prospects of the advancement of knowledge in the early history of Scotland.

The early history of Scotland extends to 1291. Archæology has recently explored the prehistoric part, and the part for which there is least literary evidence. More archæological research is needed for the period of the settlements, e.g. of the Picts.

For almost the whole early history, literary evidence is meagre. Conjecture and imagination are unavoidable, but they must not be allowed to take the place of evidence.

Apart from possible discovery of unknown literary sources, we need more exact establishment of texts, and more precise interpretation of their meaning. Study of ancient languages is necessary. Some philological acquaintance with Old and Middle Irish is needed.

Where material is scanty, it is all the more essential that sound principles of use

of historical evidence should be followed. Their observance will in general curtail what has been accepted as historical fact, and may add different conclusions.

History is the result of impartial inquiry. Prejudice destroys it. Reiteration of historical untruths does not advance a nation's honour.

Mr. Angus Graham.—Some recent work of the Royal Commission on Ancient Monuments (Scotland).

The Commission's Inventory of Orkney and Shetland is about to appear. Among its outstanding features will be : (*a*) Chambered cairns : an extensive and varied series, including a wholly new type found only in Shetland. Many detailed plans are given, notably of Maes Howe and the Rousay examples. (*b*) Brochs : much new information on architecture with many detailed plans, notably of Mousa, Clickhimin, Jarlshof, Mid Howe, and Gurness. (*c*) Stone circles : with a new plan of the Ring of Brodgar. (*d*) Early domestic sites. (*e*) Very numerous early cooking-places, comparable with the Welsh and Irish examples. The survey of Roxburghshire, now in progress, is breaking some new ground, particularly in respect of : (*a*) So-called ' forts,' which apparently include early village- and homestead-settlements, as well as simple enclosures, besides true forts. (*b*) Cultivation terraces, which are numerous and of various types. Notwithstanding divergent evidence of origin some, at least, of these may be of late mediæval date.

Mr. E. J. Wayland and Prof. C. Van Riet Lowe.—The archæology of Uganda.

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Mr. W. Fogg.—Wares of a Moroccan native doctor.

The more than sixty different medicines, charms and ingredients for charm potions, displayed for sale at the tribal markets of Morocco by an itinerant medicine man, have been properly determined botanically, geologically, and zoologically, and an investigation made of their uses. They will be exhibited, and an account given of the uses of some of the more interesting.

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Mrs. N. K. Chadwick.—The spiritual journeys of the seer.

Journeys to the Heavens and the Underworld constitute the most widespread theme in the oral literature of Asia and Polynesia, and are prominent also in the oral literature of Europe. Their geographical distribution and chronological relationship offer valuable data for the problem of transmission and diffusion. The main object of the journeys is to establish contact with spiritual beings, including the dead, and to acquire renewed physical energy and new knowledge. The types of people who make the journeys are less commonly officials than gifted individuals, though the association with local sanctuaries was commoner in the past. The oral literary forms in which the records of these journeys have been transmitted are of the greatest importance for tracing their history, and incidentally serve to throw light on the relationship of epic to drama on the one hand and to saga on the other. The relationship of the contemporary oral records of these journeys on the periphery of the modern world to the written records of such journeys from the ancient world merits special study. This study of what is, perhaps, the most widespread theme of a definite phase of spiritual literature, and of its literary forms, enables us to draw up a tentative history of that form of the seer's activities commonly called shamanism.

Prof. A. M. Honeyman.—Change of personal name among the biblical Hebrews.

The paper discusses the motives underlying metonomasia in relation to the score or more of cases in the Old Testament in which a personal name is changed.

1. Some are symbolic and perhaps purely literary in character (e.g. Na'omi-Mara).

2. Cases of translation or transliteration from one tongue to another are few (Ḥadassah-Esther ; Joseph-Ṣofnat-Pa'neaḥ).

3. Cases where there is a variation in spelling are significant not of 'enhancement of dignity,' as a tradition declares, but of the fusion of different literary and linguistic elements (Sarai-Sarah).

4. There is no clear case of a throne-name (cf. Eliaqim-Jehoiaqim).

5. Religious interest is responsible for the majority of cases. Sometimes political motives are combined (Mattaniah-Zedeqiah). The dominant religious interest is, of course, JHVHist exclusiveness (Hosea-Joshua). There remain one or two difficult cases. That of Solomon-Jedidiah is discussed in detail.

Sir Richard Paget, Bt.—Sign language and the education of deaf mutes.

According to the author's hypothesis of 1938, civilisation began when man became an artist, and thus learnt the 'trick' of symbolising things, qualities, actions, etc., one at a time. Prior to this he did not use speech ; he pantomimed events, and accompanied his pantomime with a sympathetic vocal gabble. Sir Arthur Evans suggested in 1908 that primitive men drew before they talked. Man's earliest drawings, representing the animals he wanted, or the events which he wished to bring about, were his first forms of prayer.

True speech and thought arose as man developed systematic gestural signs expressing objects, actions, qualities, etc., separately.

Prof. Alfred Sommerfelt's study of the Arunta tribe of Central Australia shows that their language still depends on gestural signs, and that they think largely in terms of events.

The born deaf to-day also think in terms of events. At present deaf children are discouraged from using their natural sign language : there is therefore no easy method of communication between the deaf child and its parents, etc.

The sign language used in Church Services for the Deaf is unsystematic and difficult for normal people to learn.

A systematic sign language is described which the parents and family of a deaf child could easily learn, so that the mind of the deaf child would develop normally ; he could then readily be taught to read and speak.

The same sign language, if taught to *all* children as a form of play, would give them a much better understanding of language generally, and would provide an auxiliary *universal* language.

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Joint Discussion with Section I (Physiology) on Nutrition and physique.

Prof. R. A. Fisher, F.R.S.

In men, as compared with other animals, development is abnormally prolonged. Growth is, therefore, extremely slow in relation to the intake of nutrients. In consequence nutrition is far less influential as a factor disturbing normal growth than might be expected from animal experiments. Moreover the opportunities for growth compensating any temporary retardations are much more extensive. Experimentally the growth response to increased nutrition is found to be remarkably small, and it is difficult to show that even this small response is of permanent developmental importance. With important exceptions, children, even the poorest

classes, must be very adequately fed. Statistics from investigations of the English poor show a gradual increase in the heights and weights of children during the last hundred years, but it is at present uncertain whether this increase is still in progress.

Dr. D. C. Wilson.

The results of nutritional examinations carried out on more than 10,000 children, in connection with dietary investigations amongst various Indian communities, are considered with a view to assessing the value of signs of deficiency disease as an index of the state of nutrition.

Mr. D. M. Lubbock.

In the human population as a whole certain growth patterns can be clearly distinguished. Some of these are discussed with reference to the diets of the races concerned. Within individual races, also, characteristic growth patterns can be correlated with differences in dietary habits. In the last thirty years measurable changes have taken place in the stature of certain population groups. The possible reasons for such changes occurring in an extremely short period of time are reviewed. The opposing claims for genetic 'selection' and for environmental, chiefly dietary, changes with which the shift can be correlated, are reviewed.

Dr. I. Leitch.

The first necessity for a just assessment of the relationship of physique to diet is an understanding of the relative importance, for the development of the individual, of heredity and environment. Nature prescribes the limits of potential development, but nurture determines the degree to which potentialities are expressed. This is illustrated by examples of plant and animal experiments. The general question of whether, or under what circumstances, prolonged subjection to a poor dietary environment results in the elimination of fast-growing types and 'selects' a suitably 'adapted' slow-growing type is discussed. The implications for the human population are indicated.

Dr. R. Broom, F.R.S.—The affinities of the South African Pleistocene anthropoids.

The dentition of the two types of Middle Pleistocene anthropoids is almost completely known, and the study of it leads to some interesting conclusions.

In structure all the teeth closely resemble those of modern man. The canines are, in the females at least, scarcely any larger than in man, and the incisors so far as known are also of the human type. The premolars, though closely resembling in structure those of man, are very much larger. The molars are almost typically human and only a little larger than those of man.

The structure of the teeth differs very markedly from those of the chimpanzee and gorilla. And we know that the milk teeth of Australopithecus are of the human type, and differ greatly from those of the living anthropoids.

From the structure of the teeth we can be quite certain that these fossil Pleistocene anthropoids are much more closely related to man than are the chimpanzee or gorilla.

They are too late in time to have been ancestral to man, but we seem justified in concluding that these Pleistocene forms are the little modified survivors of Pliocene apes which lived in Africa and perhaps Southern Asia, and that it was from some member of this Pliocene family that man originated.

The discovery of anthropoid apes in the Pleistocene with almost typically human teeth seems to the author to support the view that man originated not earlier than in Pliocene times, and possibly as late as in Upper Pliocene.

Prof. R. Dart.—Recent discoveries bearing on human history in South Africa.

Up to the time of the meeting of the British Association in South Africa in 1929, the human fossil history of South Africa was limited to the Broken Hill skull on the one hand and the Boskop remains from the Transvaal and from Zitzikama on the other. The then recently discovered and incompletely described Fish Hoek, Springbok Flats, and Cape Flats skulls seemed closely related to the Boskop type.

During the intervening decade, a continent-wide dispersal of the Boskop type in Africa has been further documented : the skeletal material from Matjes River, C.P., from Kenya in North-East Africa and from Asselar in the southern Sahara ; there is also evidence to suggest the infiltration of this or a closely allied type into Northern Africa and Southern Europe in the form of Cro-Magnon Man.

The Florisbad skull presents characteristics intermediate between those of the Rhodesian type and the Boskop type ; it is possible that some such annectant form between Neanderthaloid and Cro-Magnoid man produced in Africa the two pedomorphic types : the giganto-pedomorphic Boskop and the pygmæo-pedomorphic Bush. Genetically these two types are distinctive and appear to be sex-linked in the modern Bushman people.

The discoveries at Mapungubwe reveal a high material culture associated with skeletons of this hybrid Bush-Boskop type comparable only with those of the Late Stone Age and living Bush populations of South Africa. There was therefore a well-advanced material culture in South Africa prior to its occupation by the Bantu-speaking Negro.

The discoveries of Dr. Broom at Sterkfontein have demonstrated at least two generically-distinct humanoid Pleistocene types, whose geographical proximity and anatomical similarity to *Australopithecus* as well as their relative recentness in time indicate their emergence from the australopithecid type. The problem is to determine whether *Plesianthropus* and *Paranthropus* are not in point of fact human beings ; if so, they are the most primitive of which remains are at hand.

Dr. S. Zuckerman.—Evolution of the human brain.

The size of the Primate brain ranges from about 3 gms. in Tarsius to as much as 2,000 gms. in Man. Its basal structural pattern, however, remains the same throughout the Order and in Old World Primates the interrelation of surface to weight of the cerebral hemisphere and of its parts is more or less constant. The difference in brain-size between an Old World monkey (e.g. a rhesus monkey) and a gorilla is far greater relatively than the difference in size between the gorilla and Man. Yet few, if any, significant and measurable differences exist between the intelligence of the monkey and gorilla, whereas an enormous gap exists between the intelligence of Man and that of any other Primate. The anatomical evolution of the brain thus hardly parallels the evolution of intelligent behaviour. Experimental study has also indicated that there is relatively little difference in the level of learning ability between an ape and an animal as far removed as a goldfish. Significant advances in the evolution of human intelligence would seem therefore to be related to the development of speech and to the elaboration of a symbolic process.

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Dr. R. H. Thouless.—Mental evolution of the Primates.

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Prof. P. E. Newberry, O.B.E.—The Crane Dance.

Miss Maire McNeill.—Folklore of death cairns.

The custom of raising a stone heap, to which each passer-by added, on the spot where death occurred in the open was formerly widespread in Ireland and still exists in a few isolated districts. Not only where death occurred but any place on which a dead body, whether coffined or not, had been laid was so marked. The facts that it is still customary to add a stone to the great prehistoric burial cairns on mountain-tops, and that the humbler heaps of more recent times are sometimes said to cover graves as well as death-places suggest that we have here a relic of an ancient burial custom. The Irish countryman generally explained his action in adding a stone to the heap as honouring and helping the departed soul (each stone marked a prayer said). There was, besides, whether admitted or not, a fear that omission to do so would bring some retribution. Sometimes the thing feared was the ghost of the dead. Sometimes it seems to have been an impersonal malign power which, because death had touched that spot, had domination there. The stone heap was not only a memorial to the dead but a warning of danger to the living.

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Mrs. M. M. Banks.—Folklore of the net, line, baiting, and the boat in N.E. Scotland.

Folk-lore of the sea and fishing is generally well known, but little if any record is found of customs connected with the preparation of the tackle and the boat. Deep-sea fishing is carried out in the face of great risk and danger, and we should not be surprised to find many tabus observed in the making of implements connected with it. Two well-known Scottish folk-lorists of the north-east coast left unpublished a number of notes made in collecting records of these tabus and customs which seemed of special interest. They are quoted as revealing a system of protective rites which have escaped the notice of many other folk-lorists.

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Rev. Canon J. A. MacCulloch.—A survey of some Scottish folklore and its origins.

Scottish folk-lore is an immense subject. Though it has now largely died out, happily much of it had already been collected. In this paper only a few outstanding matters can be considered.

Scotland was inhabited by different peoples from prehistoric times onwards, and out of these has been formed the present population. There were the pre-Celtic people ; various groups of Celts—Picts, Brythons, Scots from Ireland ; Angles ; Norsemen. From their beliefs and customs the later folk-lore was evolved. It is hardly possible to assign to each group its own contribution to folk-lore. There was a primitive stratum in which all shared. These various groups tended to mingle ; beliefs peculiar to each would pass from one to another. Yet certain elements in the general folk-lore may be traced to their respective sources.

The matters considered are beliefs about fairies, dwarfs, brownies ; spirits or beings of the waters ; wells and springs ; witchcraft ; the evil eye ; second sight ; and a few other topics.

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Mr. R. Kerr.—On wooden teapots from Kongbo Province, Tibet.

Description of a type of wooden tea-pot said to be peculiar to the district of Kongbo Province, Tibet.

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Prof. J. Murphy.—Racial crossing and cultural efflorescence.

The Darwinian principle that racial crossing within a species results in an increase at once of vigour and of variability in the hybridised stock, appears to apply to

crossing within the human species. There are certain examples in history of cultural efflorescence which are traceable not merely to cultural influences but to the effect of hybridisation. There appear to be two necessary conditions : (1) that the crossing shall not be of two or more extremely different varieties, approaching specific difference ; and (2) that a period shall elapse sufficient to allow the crossing to take effect, say, ten generations or three or four hundred years. The most striking example is the efflorescence of genius in the ancient civilisations concentrated in the period between the ninth and fourth centuries B.C.

Discussion on Anthropology in Education.

Mr. N. F. Sheppard.

At present some anthropology comes into courses in history and geography ; this may be more effective than segregating the subject. Authoritative opinion to-day appears to be regarding the anthropological attitude with increasing favour. Pupils need to be helped to see civilisation to-day not as the ultimate result of a long historic process, but as an early embryonic phase in the development of human society. With the advent of universal education there is a serious risk that, the social tradition of one part of the world in one generation being so widely taught and copied, the natural development of society may be arrested. Such influences as international broadcasting and the W.E.A. tend to counteract this. Anthropology can help enormously if the past is studied primarily as a source of data for the guidance of future development.

Prof. H. J. Fleure, F.R.S.

Anthropological work in the universities raises thoughts of research into physical characters of mankind, with a view to studies of type, of inheritance and of fitness, into social organisations and their modifications through mutual contacts, and into archæological sequences important for their own sakes as well as for the interpretation of social and physical data. To secure more adequate treatment of the above in the universities it is important that anthropology should also be thought of as a subject of general culture, in order that it may have adequate student numbers and staffs, and this is the more justified in that, interwoven with human geography, it represents more than any other subject the effort to apply evolutionary thought to human affairs. The change in attitude to the world-life from dependence on dogma to appreciation of evolution is the main reason for emphasising for as many educated people as possible a study of men and environments as they actually are and as they have developed. Geography and anthropology should be interwoven and should meet one another, the geographer adjusting his perspective so that modern commercial activities are not exaggerated, and the anthropologist modifying his to show that he thinks civilised man as worthy a subject of study as the lowly peoples, the data for whom it is, of course, very urgent to gather before they sink into oblivion.

THE INTERPRETATION OF PLANT STRUCTURE

ADDRESS TO SECTION K.—BOTANY

By Prof. D. THODAY, Sc.D.

PRESIDENT OF THE SECTION.

Early investigators of plant structure aimed at discovering from the anatomy of plant organs something about the functions they perform. Owing, however, to the minuteness and intricate arrangement of the structural elements, accurate knowledge was only slowly achieved. Not only had artificial aids to vision to be improved, but the human eye itself had to be trained by their use and by the closer attention which is demanded in drawing what is seen. The same process to which the elementary student must still submit had to be worked through by the pioneers for themselves.

At the beginning of the nineteenth century some of the most elementary facts of structure were still matters of dispute, such as the nature of the spiral vessels and the pitting of the walls of other vessels. For a parallel to-day we have to look to minute histology and cytology, where structures of a lower order of magnitude and requiring a higher order of magnification to make them distinguishable by the human eye are still sometimes seen differently by different observers. Refinement of the instrument, improvement in the technique of preparation, and advances in the experience and skill of the observer, have all played their part in the progress of knowledge.

Some of the earlier anatomists, aware that the observer may easily see what he expects or hopes to see, sought to free their evidence from personal equation by hiring draughtsmen to make drawings for them. The motive was good, and we have a modern parallel in the use of photography to give independent confirmation of observations. But even photography cannot take the place of the vision of the trained observer ; those who used draughtsmen were really shirking a responsibility. It was von Mohl who consciously set his face against the practice : he maintained that drawings and descriptions must interpret the vision of the observer, who must himself strive to cultivate accurate observation, freed from preconceptions. As Sachs said of him (*History of Botany*, pp. 292–3) : 'He never forgot that the interpretation [i.e. the descriptive interpretation] of visible structure must not be disturbed by physiological views.'

The study of external form was not handicapped to the same extent by technical difficulties, though lack of knowledge regarding the physiology of the plant may in part have accounted for the development of morphology so largely as the study of pure form in the eighteenth century. A more important factor was the discovery by travellers of a wealth of new plants. The practical necessity of reducing to order the large collections that were thus accumulating,

both in herbaria and in gardens, lent outstanding importance to systematic morphology.

As anatomical data accumulated, the same sort of need led botanists to try to systematise likewise the facts of internal structure. Since the major functions to be performed are the same in all plants, the ordering of the multiplicity of forms of tissue elements and especially the various arrangements of tissues was a morphological task, in which the references to function tended to be subordinate.

The primary task of the anatomists of this period was to ascertain the facts of structure and describe them accurately and comprehensibly. The devising of an adequate terminology for this purpose absorbed much attention.

The descriptive data took their place among other morphological features as an aid to the classification of plants. As knowledge of plant physiology increased, the functions performed by the tissues became better understood, but anatomy advanced in many instances faster than the special chemical and physical knowledge, required to interpret the working of the structures discovered.

The publication of *The Origin of Species* in 1859 intensified the interest in adaptation to function. It also gave a phyletic bent to systematic comparative anatomy. For example, the evolution of vascular systems claimed attention, especially under the stimulus of palæobotanical discoveries of far-reaching importance, in which British botanists played a leading part.

Difficulties and disappointments were however in store for those who followed each of these two directions of thought and investigation, both the adaptational and the phyletic.

Structure and Function.

Under the influence of Darwin's concept of 'Survival of the Fittest,' adaptation received exaggerated emphasis, and a tendency to assume all structural features to be adaptive was strengthened. It was even tacitly assumed that, having been through the mill of competition, plants should be well-nigh perfectly adapted to the habitats in which they maintain themselves successfully.

It is, of course, essential that the structure of plant organs should enable them to carry out their functions adequately ; but perfect adaptation of tissues to their functions would be difficult to define.

The study of xerophytes provides an instructive example. The peculiar features of structure which impart to the vegetation of dry regions a characteristic aspect, contrasting markedly with that to which dwellers in moist temperate regions like our own are accustomed, were interpreted by Schimper as adaptations for the control of the supply of water, chiefly by limiting the loss of moisture from the exposed shoot system.

Schimper was a pioneer in the study of vegetation from the point of view of a physiologist ; he ranged widely, his output of research was considerable before an untimely death cut it short, and his ideas and example stimulated the researches of others after him.

He did not, however, escape the pitfalls that have often awaited attempts to infer function from structure. He observed that the characters exhibited

by xerophytes were also possessed by plants in certain other habitats. In salt marshes the plants were predominantly succulent ; on wet moorlands wiry grasses and ericoid plants with minute rolled leaves were characteristic, though water was usually plentiful. Schimper concluded that water in these habitats is difficult to absorb, and that for this reason the plants had to conserve the water they obtained.

This view, that such habitats are physiologically dry though physically wet, proved later to be erroneous ; but meanwhile it helped to concentrate attention on the reduction of transpiration, and xerophytes came to be defined not in terms of habitat but in terms of structure. Adaptations for reducing transpiration were regarded as characteristic of them as a class ; although little experimental evidence existed for the assumption that they actually transpired at a low rate.

When the experimental gap began to be filled, it came as a shock to many to learn that xeromorphic plants—i.e. plants with the aspect and structure of xerophytes—might transpire very vigorously. Kamerling (1914) went so far as to argue that such plants were only 'pseudo-xerophytes' and that the only true xerophytes among the plants he experimented with were certain succulents, which actually showed a low rate of transpiration.

Closer study of the plants of dry habitats in the field, experimental work on their water relations and general physiology, and fundamental physiological researches, have combined to show that the functional interpretation of the structure of xerophytes is by no means a simple task.

In the first place, plants of very different structure are found growing together, as constituents of the same vegetation, occupying adjacent positions in the same habitat. Not only do we find succulents, storing water in bulky tissues, alongside of sclerophylls, with little storage capacity but heavily protected epidermis, but we also find non-succulent soft-leaved plants, with no obvious protection. Others again have thin cuticles but hairy coverings of various kinds. These species coexist successfully, but they must clearly meet the difficulties imposed by their environment in different ways. In respect of the control of transpiration they cannot all be equally well adapted.

Having regard to thickness of cuticle, it has been shown by Kamp that mere thickness is not a safe criterion of efficiency, for cuticles differ in quality : a thick cuticle may be relatively pervious and afford less protection than a thinner but more highly waterproof one.

It has come to be realised, from a consideration of such difficulties and the results of experimental work, that before the physiological adaptation of plants to their environments can be properly assessed we need far more exact knowledge regarding the quantitative relations of their different functions to the environmental factors, and regarding the balancing of those functions.

Meanwhile the aim of physiological anatomy should be the descriptive elucidation of the structure of organs, and the accurate assessment, confirmed as far as possible by quantitative experiment, of how the structure works. The question to be answered is not how an organ is adapted to its function, but rather *how its form and structure affect its functioning*.

Quantitative investigation of the effects of minute structural features is often beset with great difficulty. This has indeed led plant physiologists to resort more and more to the simplest organisms for fundamental research. Schimper

wrote his *Plant Geography* before the laws which govern diffusion of gases through multiperforate septa, like the epidermis of a leaf with its numerous fine stomatal pores, had been discovered. It was known from Stephen Hales's experiments, published in 1727, that ordinary leaves might transpire at a rate surprisingly high in comparison with evaporation from a freely exposed moist surface ; but it was Brown and Escombe's work which showed, in 1903, how remarkably efficient multiperforate septa are.

Their critical experiments were made with artificial septa. These simplified models were, however, on a far larger scale than the epidermis of a leaf. The application of their results to membranes with much smaller and more numerous pores was a process of extrapolation, which left room for differences of opinion. We have not even yet reached finality in the solution of problems presented by stomatal diffusion, as affected by wind and other external conditions and by the size and proximity of the stomatal pores, although much intensive work has advanced our knowledge considerably ; nor do we know just how much effect to attribute to the sinking or raising of stomata, or other special devices.

While the exact laws of the diffusion of gases through stomata are difficult to establish, it might be thought that the *distribution* of stomata at least would lend itself readily to adaptational interpretation. The truth is again contrary, for teleology has met one of its most serious rebuffs in this very field.

The adaptational outlook led to the expectation that xerophytes would have fewer stomata than plants less exposed to drought ; and that, within a species, individuals growing in drier places would likewise be similarly protected. Actually, the facts point very largely in the reverse direction. Zalenski showed that more exposed leaves had a higher stomatal frequency. Much subsequent work has confirmed in a general way the truth of Zalenski's conclusions. Salisbury's statistical studies (1927) in particular have shown that, on the whole, plants in more exposed places have a higher stomatal frequency, and that for a given species the proportion of stomata to epidermal cells is more constant over a range of moisture conditions than stomatal frequency, variations in which are to be interpreted largely as the consequence of different degrees of expansion subsequent to the initiation of the stomata.

This turns the attention away from adaptation to the process of development. Salisbury's results indicate that stomatal frequency is determined by factors at work in two phases of leaf development. The first is the formative phase in which the position and number of stomata are determined in relation to the epidermal cells, mainly by internal influences depending on the hereditary make-up of the plant. The second is the expansion phase, in which the degree of separation of the stomata, already initiated, is determined. The degree of expansion is dependent upon the water supply to the leaf during this phase of growth, so that the better the water supply the farther apart are the stomata.

We are thus led to approach the phenomena from an entirely different angle, and inquire into the causes, as well as into the effects, of structural features.

From the causal point of view, the early, formative phase is the more interesting ; but it usually overlaps the expansion phase to a considerable extent, so that it is not always easy to distinguish them clearly. External

conditions, of course, do affect also the formative phase. In leaf development, for example, the well-known differences in structure between sun and shade leaves, involving thickness and the differentiation of palisade tissue, may in part be traceable, like the difference in area, to differences in water content during development. It was found by Schröder (1937) that twigs in shade positions could be induced to form leaves with the characters of sun leaves by notching the stem and so restricting their water supply.

This example does indeed suggest that even the greater breadth of the shade leaf is not a simple direct effect of an easier water supply, for with greater growth in area goes less growth in thickness. The outstanding features of structure are determined in the formative phase by internal regulative factors.

Goebel has shown how problems of development may be attacked inductively in his *Gesetzmässigkeiten im Blattaufbau* (1922). The general result of his studies of leaf development was to bring out the repetitive nature of the patterns that are laid down, the units of a pattern showing, at the time of initiation, remarkable constancy of scale. Thus at the growing edge of a fern frond bifurcation of the veins keeps their spacing within certain limits, just as the size of cells in meristems tends to remain more or less constant owing to division when an upper limit is reached. The uniformity of size of the meshes in a net-veined leaf is a similar phenomenon which has been studied by Schuster (1908). Stomata and also root-hair initial-cells show an approximation to uniformity of spacing at their initiation, however much the fact may subsequently be obscured by expansion of cells between the initials, or inhibition of their further development. Küster has emphasised the correlational aspect of such regularities, as depending upon mutual relations between the different tissues or structural elements that make up the pattern.

Another example of a quantitative approach to problems of adaptation is afforded by attempts to correlate the dimensions of parts served and tissues serving them. It is obvious that as the foliage of a tree increases in extent the amount of conducting tissue in the stem increases too ; and that from the small twig through branches to the main trunk the amount increases parallel with the increasing number of leaves to be supplied. Jaccard drew attention to the quantitative aspect of this relation ; and in 1920 his pupil Rübel examined it in greater detail for the herbaceous plant, *Helianthus annuus*. Salisbury had already in 1913 correlated the vascular structure of petioles with the dimensions of the leaf blades, with special reference to the xylem and transpiration.

The correlations displayed were not exact and showed considerable variations. Functionally therefore they fall short of perfection. Yet they are remarkable enough, and specially worthy of note when we begin to inquire how such correlations come about. How is it that the development of different parts is balanced ? Again our attention is directed away from the purely functional to the causal aspect of the phenomena, centring in the process of development.

In other cases there is not only increase in amount of vascular tissue but increasing complexity in its form and distribution with increase in the size of the system to be supplied. This relation between scale and complexity has been emphasised especially by Bower, and elegantly illustrated by him and his collaborators. The functional interpretation of this is less obvious, and cer-

tainly more complicated. Bower has drawn attention to the fact that the surface of contact between the vascular tissues and those around them is increased by the complexities that arise as the scale increases. In this way the diminution of surface relative to bulk, which is the natural result if size increases without change of shape, is partly compensated. Wardlaw's (1926) calculations for stems of Lycopodium, for example, illustrate this clearly.

Bouillienne (1928) found that the number of vascular strands in roots of the palm *Iriartea exorrhiza* of different sizes varied as $(\text{diameter})^{\frac{3}{2}}$. This relation requires further analysis from the functional point of view. Bouillienne's scale drawings show that the strands in larger roots are larger as well as more numerous.

On the other hand, as in other instances already discussed, the causal aspect of the phenomena may prove to be of greater significance than any consideration of the functioning of the mature root. In these large palm roots the strands of xylem and phloem, which, as usual in roots, alternate regularly, present very forcibly the appearance of a repetitive pattern around the periphery of the central cylinder. The pattern is determined at an early phase in the development of any given segment of the root, while it is still near the growing point and before it has reached its full diameter. It seems likely that, as in the cases previously discussed—stomata and leaf venation—the unit element of the pattern at its initiation varies in dimensions only within narrow limits, so that the number of repetitions is determined by the spatial relations at this early stage. Subsequent growth in diameter of different parts would then modify these relations, as it does stomatal frequency and venation density in a leaf. The number of strands would thus depend on the circumference of the central cylinder at the time of initiation, not on the ultimate size of the mature root.[1]

The same point of view may be extended with appropriate modifications to all the correlations of complexity with size that have been emphasised by Bower. The convolutions and other changes of form which the vascular tissues undergo have functional consequences ; but they also need investigation as the outcome of developmental processes taking place according to definite laws which causal analysis should reveal.

In cases of the kind just considered the determining factors may be inherent in the developing part itself and involve simply the mutual relations of the tissues composing it, during the period of their differentiation. When, on the other hand, correlations between amount of vascular tissue in the stem or petiole and area of leaf surface are considered, an interaction between one part and another is implied. This aspect has been investigated both experimentally and by anatomical analysis.

Jost's classical experiments on Phaseolus seedlings (1893) showed that severance of leaf-trace bundles in the middle of an internode interrupted their development below the point of severance, but not above it, although neither part could function normally. Jost concluded from the results of several

[1] Bower, in the new edition of his *Botany of the Living Plant* (1939) gives data (p. 594) relating number of xylem rays to diameter for roots of *Colocasia*, stems of *Lycopodium*, and rhizomes of *Psilotum*, which fit well with this conception ; expansion growth in these cases appears to be uniform enough not to obscure the proportionality between circumference and number of repetitions.

experiments of this type that the development of the bundles is dependent upon the maintenance of continuity with the leaf to which it belongs. He also showed the connection between cambial activity in a woody twig and developing organs above the part in question.

In herbaceous plants, cambial activity at any given level often exhibits local variations which are related to active development of different leaves above. In the sunflower this is conspicuously shown (Thoday, 1922). In the earliest phase of development of a particular internode the bundles connected with the next leaf above are precocious, and grow *pari passu* with this leaf. When the leaf is full grown, further growth of its leaf-trace is for a time greatly retarded, the intrafascicular cambium remaining relatively inactive and forming only a little parenchyma. Elsewhere at the same level other bundles continue to grow ; some of the smallest, which represent the integration of leaf-traces from leaves higher up and still in active growth, develop into great wedges of secondary tissue, which come to be far more conspicuous than the erstwhile principal bundles.

That the developing organs actually influence the growth of the stem below them, to considerable distances, is a natural inference from the correlations just outlined, as well as from the experiments of Jost.

Strong support for the reality of such influences has been forthcoming from one of the most spectacular advances in knowledge in recent years—the discovery of chemical agents controlling growth, which was an outcome of investigations on the curvature of shoots in response to light. The greater growth of the oat coleoptile on one side, which produces curvature, has been shown to be due to the transport downwards of a diffusible chemical substance in greater amount on that side. Other tropic curvatures are similarly produced.

The growth-promoting substances, called auxins, are highly active. One fifty millionth of a milligram produces a measurable effect on the oat coleoptile. The amounts present in plant organs is therefore extremely small, and this is a serious obstacle in the way of identification of such hormones. Nevertheless, the chemical constitution of certain natural auxins has been elucidated. Some other substances of simpler constitution, which can be synthesised in the laboratory, have also been found to influence growth in a similar way.

Auxins have now been shown to be of very general occurrence. They are produced especially by actively growing parts of shoots—sprouting buds, shoot-tips and young expanding leaves. They not only influence growth in length, but also produce other effects which are of greater interest in the present connection. For example, they stimulate the production of roots from the base of cuttings. Both in this phenomenon and in the phototropic reaction the auxin moves normally only in the downward (basipetal) direction. This polar transport is still not understood, but it is of the greatest significance. It has been conclusively demonstrated by quantitative experiments for the oat coleoptile and evidence is accumulating that it is the general rule.

Another phenomenon in which auxins play a predominant part is the dormancy of lateral buds in the presence of an active terminal bud. If the tip of a shoot of a bean seedling is cut off, the buds in the axils of the leaves or cotyledons below become active and produce shoots. If, however, auxin is applied in a lanolin paste to the cut surface at the top, the sprouting of the buds is inhibited.

How auxin produces such effects is still under investigation. Experiments with defoliated lemon cuttings made by Cooper (1936) suggest that it may bring about or accelerate the basipetal transport of other substances, for, when a short piece was removed from the basal end of an auxin-treated cutting after 40 hours, repetition of the auxin treatment did not induce it to form roots. Something else, it is thought, must have been accumulated in the base of the cutting and been removed with it.

Later experiments by Went seem to point in the same direction. Went postulates special hormone-like substances, necessary for the formation of particular organs, which he calls calines—rhizocaline, caulocaline and phyllocaline, for root, stem and leaf respectively—the movement of which is influenced by auxin. This is a revival in modified form of Sachs' concept of ' Stoff und Form,' for which indeed support has come recently from another direction.

Since the remarkable discoveries of Garner and Allard, it is known that many plants require special conditions to bring them to the flowering stage and that, without these, they may continue to produce none but vegetative organs. The special conditions are sometimes a long day, sometimes a short day, according to the species. Some plants require treatment at a low or a high temperature during germination as well. Making use of these discoveries it is possible to keep one plant purely vegetative and induce another to flower, by giving each the appropriate conditions. Experiments by Hamner and Bonner (1938), Melchers (1939), and others have shown that a plant in the flowering phase differs from that still in the vegetative phase in the presence of diffusible substance. This will pass over from one to the other, if cut surfaces of the two are placed in contact, and induce the hitherto vegetative individual to flower. The substance is not auxin, nor apparently any of the other active substances previously encountered.

Still another effect of auxin is of particular interest for the study of plant structure. It has been shown experimentally by Snow (1935) and confirmed by others that auxin stimulates cambial activity. Söding (1937) has actually detected auxin in the cambium of trees in spring and summer. He states that it appears there a little in advance of the resumption of cambial activity in the spring. Since it is produced by developing buds and young leaves and travels downwards, the downward spread of cambial activity from the base of the awakening buds in spring is thus accounted for in terms of an effect of auxin which is experimentally demonstrable. The basipetal conduction combined with tangential localisation exhibited in this instance gives strong support to the interpretation, already suggested, of the localised cambial activity in the intact sunflower stem, as indicating a causal influence proceeding downwards from the actively growing leaves.

Certain other phenomena involving localised growth have been traced to auxins or substances similar to them in their effects. In the stimulation of fruit growth, the production of root nodules in Leguminosæ, the proliferation of tissues associated with crown gall disease and the formation of insect galls, evidence has been found of the activity of auxins, though in gall-formation, at least, other stimulating substances may also be involved.

Evidence has also been adduced of stimulating agents of a chemical nature liberated from wounded tissues themselves. Haberlandt (1913–14) distinguished two factors co-operating to induce the cells below a wounded surface

to resume a meristematic condition and produce a periderm to cover the exposed tissues. These were the presence in their neighbourhood of damaged cells and of phloem. Application of the juice of mashed tissue caused undamaged cells to start dividing and Haberlandt inferred the presence of a ' wound-hormone.' Small pieces of tissue, however, showed cell division only if phloem was present. Activity was usually initiated first near the phloem and extended thence into the parenchyma farther from it. Haberlandt concluded that a second hormone, which he called ' leptohormone,' was at work.

Haberlandt's wound-hormone did not meet at once with general acceptance. Priestley found the preliminary blocking of the cut surface by fatty materials an important factor. Recent experiments by Bonner and English (1938), however, appear to establish beyond a doubt that wound-hormones do exist. They used as test material the inner surface of broad bean pods and devised a technique for comparing quantitatively the effectiveness of various extracts and solutions. They succeeded in concentrating and purifying from extracts of bean pod tissue a highly active substance to which they gave the name ' traumatin.' Heteroauxin and various other substances were quite inactive in comparable dilutions.

Susceptibility to traumatin varies widely even among closely allied forms.

As regards ' leptohormones,' Lamprecht (1918) obtained evidence of passage from one piece of tissue to another placed in contact with it, when the two pieces were from the same or from allied species. More distantly related or unrelated species gave negative results.

It follows that neither wound-hormones nor leptohormones are identical for a wide range of plants, as the auxins appear to be.

Brown's experiments (1936–7) with Balsam Poplar also merit attention here. These have shown that in the neighbourhood of a wound the activity of the cambium is stimulated, an influence emanating from the wound itself supplementing that of auxin.

The demonstration that such hormones exist and are effective in influencing plant development is of far-reaching significance. It is a challenge to students of plant structure to view their data dynamically. The statement that one part of a plant influences another is no longer to be understood merely as a convenient way of expressing a correlation, in a figurative sense, but is a legitimate hypothesis in a causal sense. The corollary is that the processes of development and differentiation should be closely followed and analysed, with the definite object of revealing the causal sequences and interrelations and framing the fundamental questions which await experimental solution.

The Phyletic Outlook.

Let us turn now to the other main line of anatomical investigation, phyletic studies.

The evolution theory gave a new meaning to natural relationships, as revealed by the systematist, and a new aim to the systematist himself. Previously a natural system was conceived as a system of classification depending on the balance of similarities, estimated from a consideration of all the characters of the species, as compared with an artificial system depending on

particular characters selected for their convenience. The ancestry of species now became, in theory, the main basis for a natural classification, to which indeed other evidences were to be subservient.

The aim thus became the construction of an evolutionary tree, not just a map of the foliage as seen from above. Early work with this aim was enthusiastically undertaken and led to the accumulation of a vast amount of new knowledge, in breadth and in detail, about the range of form and structure in the vegetable kingdom. The main hope was, however, deferred. It was soon realised that, as similarities in some features are often accompanied by dissimilarities in others, similarity might not always signify relationship. Fossils themselves, moreover, provided clear evidence that similar organs or structures have been evolved independently along different lines, by different phyla, so that the possession of seeds, for example, is not evidence of common ancestry for all seed-bearing plants.

Modern genetics reveals, as the most prolific cause of variation, irregularities in the process of nuclear division and the behaviour of the chromosomes, and changes in the substance or structure of the chromosomes, which appear to be entirely erratic and haphazard.

If, however, we turn from the minor variations which differentiate species and horticultural varieties and survey the major events that have marked the evolution of plants, it is difficult to regard these as haphazard. Besides seeds, already mentioned, a number of features are found with even wider distribution, common to groups which cannot be traced to a common origin. Such are the alternation of sexual and asexual generations, traceable throughout vascular plants, in Bryophyta and in many Thallophyta; archegonia; the formation of spores in tetrads, following a reduction division; air-space systems in the sporophytes of land plants, and stomata associated with them, remarkably similar in general plan and behaviour in different groups; vascular tissues, showing an astonishing degree of resemblance in detail over a wide range of vascular plants and, in the case of sieve-tubes, found in some seaweeds as well; then fertilisation, evolved also in the animal kingdom, and the cell as the unit of construction in plants and animals, with nucleus differentiated from cytoplasm in all but the lowliest organisms; the nucleus with its chromosomes and their highly organised behaviour in division. The enumeration need not come to an end on the plane of cellular, structural organisation, for chemical parallels are quite as remarkable. Consider, for instance, the similar enzymes and enzyme complexes responsible for carbohydrate metabolism in yeast, in the higher plant and in animal muscle; the hæmins found in plant and animal cells alike, and the related substances, chlorophyll in the green plant and hæmoglobin in animal blood, with uniquely important functions. Finally there are the proteins and other important basal constituents of living matter.

The idea was suggested by F. F. Blackman in 1921, in reference to Nef's work on the interchangeability of carbohydrates, that the biologically important carbohydrates are just those which are chemically most likely to arise—most readily formed, most stable, etc. May we not extend this idea to explain the universality of particular chemical compounds or radicles—like the amino-acids, limited in number, found in protoplasm?

The picture of the origin of life presented by Oparin, in a book recently

translated into English, suggests very forcibly the idea that inherent chemical probability determined the occurrence first of simple carbon compounds, such as are still present in the atmospheres of the outer planets, then of more complex compounds formed from them, and colloidal substances and associations of substances, many of them with catalytic properties. The particular substances formed must have been influenced by the general or local conditions existing at the given epoch. Moreover, the formation of more complex compounds would be less frequent than that of the simpler ones, by reason of the greater number of units co-operating to form them and the smaller probability of the necessary contacts ; but the uniqueness of events leading to the origin of living matter has probably been exaggerated.

The conditions for an epoch-making event like the arrival of chlorophyll were provided by the previous course of chemical evolution, in common characters of living matter, and by particular variants of them under particular conditions, which may have occurred but rarely in combination, but are hardly to be envisaged as unique.

The production of chlorophyll was epoch-making because it made possible the organisation of a photosynthetic system, far more efficient than any pre-existing photochemical system, which must have starved out all others by reducing to a very low level the concentration of carbon dioxide in the medium.

This example will suffice to suggest, in addition to the principle that new features arose because their occurrence had become in some degree inherently probable, a second, namely, that having arisen they survived because they found a place in a dynamic system, harmonising and co-operating with it. Notice that it was not merely chlorophyll that was evolved, but a system that could produce chlorophyll, one derived presumably from a pre-existing system capable of producing pyrrol and hæmin compounds. It is that which is passed on from one generation to the next.

If it is legitimate to regard chemical events in this way, as occurring with a frequency concordant with their inherent probability, may we not carry this idea on to the higher plane of cellular organisation and structure? To do so is to direct attention to the nature of that stability and developmental harmony which are so conspicuous a feature of living organisms ; for persistence and occurrence become more and more determined and limited by the pre-existing system through which evolution works. Cytogenetics has familiarised us with lethal genes which do not harmonise with the remainder of the system and are therefore eliminated. Natural selection of harmonious changes may have been more important than elimination of functionally unfit mature organisms. It is developmental harmony which is important, of which functional efficiency of adult organs is but a part.

We are thus once again led to the consideration of development. If we can obtain light on the laws of harmonious development, we may be in a better position to understand the nature of those major changes which the great pageant of evolution unfolds.

It is perhaps hardly necessary to re-emphasise the causal nature of the problems ; but it may be well to point out that comparison of successively formed parts of the same individual shoot is not necessarily a developmental study. There is no developmental connection between successive mature leaves. The causal sequence is from young primordium to the mature leaf,

and, in the apex itself, the sequence of phases through which it passes, affecting its form and scale and the nature of the promordia that arise from it.

Similar considerations apply also to phyletic morphology. If comparative morphology suggests that a particular course of evolution is probable, on the ground that a series of forms can be arranged in a graded sequence, it must not be overlooked that they cannot be treated as three-dimensional patterns, as some recent speculations on the evolution of fossil leaf-forms appear to do, without regard to their modes of development. The patterns to be compared are four-dimensional.

A relevant illustration is afforded by the use which has been made of the woodiness of the lower parts of the stem of many herbaceous Dicotyledons, as an argument for the evolution of herbs from trees. This woodiness has been treated by some as a primitive character and the diminishing woodiness upwards as an instance of the recapitulation in ontogeny of the presumed phylogenetic sequence. Close examination of the phenomenon in the stem of the annual sunflower (Thoday, 1922) has shown that the differences between different levels depend mainly or solely on two factors. The first of these is the small size of the seedling stem and the increasing scale of all the new parts as the plant grows. The second is the longer time that the basal internodes have, in which to form secondary tissues, before the life cycle comes to an end with the production of seed. When allowance is made for these factors, the fundamental features of the development of stem structure are identical at all levels, except at the very base, where the transition to root structure necessarily involves accommodation between stem and root. Any sound basis for application of the recapitulation theory thus vanishes.

Analysis of the differences between the developmental organisation of the stem in herb and tree does, however, enable us to understand better the nature of the fundamental changes that must have taken place if herbs *were* evolved from a primitively woody group. In the sunflower more parenchyma is developed in proportion to vascular tissue and the primary rays between the bundles appear to separate them physiologically, so that the stimulus to cambial activity from the developing leaves is tangentially localised. In trees it is more evenly distributed. The bundles of the sunflower stem show indeed a remarkable degree of independence of the tissues around them, and cause considerable disturbance by their growth. It appears likely that transport of hormones or food materials or both is canalised to a much greater degree than in trees.

Seedling Structure.

As an example of the application of causal principles to old problems I propose to consider the structure of seedlings. The study of this subject had reached a peak in Britain when the Association last met in Dundee, and Miss Sargant took it as the subject of her Presidential Address to this Section at Birmingham in the following year.

British workers had approached the subject with a phyletic aim, largely encouraged by the success which had attended the study of fern sporelings, in which the earliest vascular systems were of primitive type, and transitions from the simple protostele to more complex arrangements in the grown fern plant

appeared to be obvious recapitulations of the phases of increasing complexity through which the ancestors had presumably passed. It was expected that primitive features would be discoverable also in the seedlings of higher plants.

The ways in which the transition is effected from the arrangement of tissues characteristic of the root to that characteristic of the stem had already been surveyed and classified for mature seedlings by van Tieghem, who emphasised the functional continuity of tissues from root to shoot. The later more intensive study of seedlings in various stages of development led, however, to the discovery that root structure was often to be found above the root in the hypocotyl, and that exarch xylem strands directly continuous with exarch xylem poles of the root might even extend into the cotyledons. Phloem occurs in two strands on the flanks of this xylem. More xylem is formed later on the inner side of each phloem strand. The resulting arrangement was described by E. N. Thomas as a double bundle, by Gravis as a 'triad.' It was held by them and others to be of phylogenetic significance.

Chauveaud demonstrated that the exarch xylem pole is a more general feature of the hypocotyl of seedlings than had previously been suspected. It had often been overlooked because, although it is commonly present at a very early stage, it often disappears during the growth of the seedling, being disrupted by the expansion of the tissues around it, or even actually resorbed. Chauveaud too regarded the exarch protoxylem as a relic of primitive ancestral structure. He described the sequence seen in the differentiation of the xylem, first centripetal, then lateral and finally centrifugal, on the inside of the two flanking phloem strands, as a recapitulation of vascular evolution by the course of development at one level. He also claimed that this change from centripetal to centrifugal differentiation of xylem occurred more rapidly at higher levels, so that in this sense there was a recapitulatory sequence to be observed from below upwards, the root retaining the primitive arrangement longest. In the epicotylar stem the early phases are generally omitted entirely and only the centrifugal phase occurs.

The British and French schools present an interesting difference. The former, by a wide comparative study, sought for evidences of relationship which would help to fill in the gaps left by fossil evidence, and assist the reconstruction of the phylogenetic history of the different groups of plants. The French school studied fewer examples intensively and was interested in the evolution of types of structure rather than the phylogeny of groups.

Both schools eventually developed cleavages. The broad survey achieved by British workers revealed large differences within closely related groups, which made it more difficult to interpret resemblances as of phylogenetic significance. A high degree of correlation was observed, on the one hand, between slender smallness of seedlings and diarch root structure, with two xylem poles extending right up the hypocotyl; and, on the other hand, between large diameter and tetrach or polyarch structure, with stem-like pattern in the hypocotyl. Number of bundles in cotyledons and hypocotyl was correlated with size of cotyledons, and the diameter of the hypocotyl was also correlated with number of bundles. Both Compton (1913) and T. G. Hill and de Fraine (1913) emphasised seed size as an important factor influencing seedling structure, the latter authors referring to the need for more knowledge of the interrelationships of plant members and the influence of environ-

ment, 'in a word, the influence of physiological necessity on morphological expression.'

Another factor of a similar kind was the influence of the plumule, the traces from which, when precociously developed, shared with the cotyledon traces in the early structure of the hypocotyl. In certain cases, particularly among the Amentiferæ, the traces from the plumular leaves were found to be triads like those from the cotyledons (Davey, 1916), and these with their central xylem strand extend above the cotyledonary node into the epicotylar stem itself. Phylogenists were inclined to interpret this as a more extensive persistence of primitive structure in a relatively primitive group. It appeared also to provide support for Chauveaud's notion of 'virtual suppression' of the centripetal xylem in the epicotyl in other cases. But the occurrence of a root-like solid core of xylem in the epicotyl of the Vicieæ, an advanced group among the Leguminosæ, hardly harmonises with phyletic ideas, as Compton pointed out, and makes phylogenetic interpretations appear less certain. Thus opposing views emerged, the one emphasising the general features as of broad phylogenetic significance ; the other pointing to the variations, related to functional requirements, as discounting any such presumption.

The French and Belgian anatomists, working intensively rather than extensively, diverged regarding the nature and mode of achievement of continuity between root and shoot. Chauveaud found the first xylem strands in the young seedling continuous from root to cotyledons from the beginning, and regarded the seedling axis as a unitary formation, with initially primitive structure. The root retained longest this primitive arrangement which reached its greatest development there ; but with distance above the root a transition to the more advanced structure characteristic of ordinary stems took place more and more quickly.

It was this view of 'basifugal acceleration,' as Chauveaud called it, which was controverted by Bugnon in 1922 on the ground that the acceleration was only apparent and was really due to the greater disorganisation of the early phase in the upper part of the hypocotyl by intercalary elongation there. Behind this criticism, however, was a fundamental difference of attitude. Bugnon doubted the validity of the recapitulation theory as applied to seedlings and tried to approach the facts objectively, without phyletic aim or preconceptions, from the developmental point of view. He first compared the origin and development of the vascular traces of cotyledons and foliage leaves. As has been recognised since the work of Sanio, the differentiation of the leaf-trace bundles progresses basipetally from the node. Bugnon observed that in *Mercurialis annua*, as in many other plants, they normally fork into two, so avoiding incoming bundles immediately below, before uniting with other bundles lower down. The cotyledon traces likewise fork, though they do this sooner and in relation to the vascular system of the root. According to Bugnon, there is nothing peculiar about a double bundle ; it is a normal feature of the conjunction of leaf traces with a vascular system already present in the axis.

Turning to the radicle, Bugnon notes that the root structure is quite typical. All other roots, however, arise from organs already differentiated. They form their own characteristic pattern of vascular arrangement, and this is linked by commissural elements to the appropriate tissues already present in the parent organ. In the case of the radicle, an exactly similar root apparatus has to be

linked up, not with tissues fully differentiated, but with tissues still in a meristematic condition. The connecting tissues are therefore similar to ordinary conducting strands, not special commissural elements. In fact, the exarch xylem strands are continued upwards through the hypocotyl to a point just below the fork in the cotyledon trace. Bugnon points out that when the exarch protoxylem is formed the distance is very short, and centripetal protoxylem could be propagated without hindrance in the procambial tissue of the hypocotyl.

Bugnon thus regards the process as one of conjunction (*raccord*) of two separately initiated systems, which as far as the xylem is concerned are dovetailed together, not continuous initially. This view has much in common with those put forward by Dangeard, Sterckx and Gravis ; but his interpretation, as far as it goes, does seem to be causal, not purely formal.

Like the earlier view of Sterckx, it implies distinct and well-defined categories of plant members. British anatomists were no more willing than Chauveaud to accept this basis, since they saw in the root stele a representative of the primitive protostele which they regarded as the prototype from which stem steles were also evolved. They thought of the root as therefore but a specialised part of a primitively undifferentiated branching axis, which had retained primitive features in relation to the function it had assumed in the course of evolution. They were unable to regard the seedling axis as anything but a unity from the beginning, an organ which must from a remote ancestry have had its own inherent vascular pattern, whereas Sterckx made a ' patchwork ' of it (Compton, 1913).

In trying, however, to assess the value of Bugnon's interpretation it must, I venture to suggest, be admitted, that phyletic considerations are irrelevant to the question exactly how given structures arise during the development of the individual plant.

Bugnon did not, as far as I am aware, attempt to extend the same principles of interpretation to the wider range of facts which have been brought to light, and it appears worth while to see how far this can be done.

In the first place, from a causal point of view, certain principles may be regarded as established.

The first is the power of self-determination inherent in growing organs and especially in apical growing points—each developing a characteristic pattern of external form and internal structure.

The second is the influence of apical developing organs on the structure of other parts still capable of growth—this applying particularly in the basipetal direction and therefore mainly to the influence of the shoot apex and young leaves on the parts below them.

With regard to the root, a spectacular demonstration of its power of self-determination has been provided by Philip R. White who, following on the pioneer work of Robbins and Maneval, succeeded in 1934 in proving that root-tips cut from the plant can be grown continuously for years in a nutrient solution containing the essential salts, sugar, and a small concentration of an extract of yeast. Further investigations by him and others have shown that the important constituents of the yeast extract are vitamin B_1, or precursors of it, and traces of accessory mineral elements. Certain amino-acids are at least beneficial ; but Robbins and Schmidt (1938) have recently found that tomato roots

require no other source of nitrogen than nitrates and so must be able to synthesise amino-acids for themselves.

In the intact plant, roots obtain mineral elements direct from the soil. It is clear therefore that they need nothing more from the shoot system than carbohydrate, vitamin B_1 and perhaps amino-acids. Given these nutritive materials the growing point of the root is able to produce indefinite lengths of normal root, in the absence of any stimulating or regulating influence from the shoot. This has been demonstrated for plants as different as tomato and wheat, maize and pea. It may be remarked in passing that separation of a root-tip from the whole plant does not induce it in these instances to regenerate the missing parts.

The structure of the roots in these cultures is the normal primary structure. They branch freely by the production of endogenous lateral roots in the usual way. It is of great interest, however, to learn that in Dicotyledons (pea and tomato) no secondary growth occurs, as it would if the roots were attached to the plant ; no cambium is formed, nor any secondary periderm.

The root system, then, is completely self-determining as regards its primary structure.

It might be objected to this conclusion that the root-tips in cultures all came from other roots, developed initially in organic union with shoots, and that the characteristic pattern of the root stele is not inherent in the root apex but induced. Doubtless the initial *orientation* of the pattern is influenced in many cases by the position of the root primordium in relation to the tissues adjoining it. The lateral roots of Dicotyledons commonly have a diarch xylem plate, orientated parallel to a xylem strand in the parent root to which it is joined by linking elements. It has been shown, too, by Jost that, if a tip is removed from a root and it regenerates a new tip, the vessels formed are mostly in continuation of those already present in the stump.

Nevertheless, the impression remains that the pattern itself, as distinct from its orientation, is inherent in the root-tip. Its essential features persist in spite of changes in the number of strands.

Further evidence pointing in the same direction has been obtained in investigations, parallel with the culture of excised roots already described, but aiming at discovering the smallest portion of root-tip which is able to grow normally. As long ago as 1922, Kotte recorded that tips of pea roots only 1 mm. long, half of which was root-cap, produced 2 or 3 cms. of normal root, with triarch xylem and typical endodermis and root hairs. Similar results were obtained by Scheitterer in 1931 and by Robbins, Bartley and White in 1936. These latest results with maize, pea and wheat roots appear conclusive. Wheat root-tips cut off at the base of the meristem formed complete roots, while the stumps regenerated new meristems. Maize tips cut obliquely or longitudinally into pieces formed complete roots if they included part of the plerome. The root-cap of the maize roots was about 0·32 mm. long ; but, on agar medium, tips only 0·5 mm. long or less grew in a good proportion of cases, and those 0·8 mm. or over in practically 100 per cent. Of course, the proportion of successes rapidly diminished below 0·5 mm. but the smallest to grow was only 0·32 mm. long, i.e. the average length of the root-cap. It is difficult, in the face of these results, to suppose that the meristem always included tissue in which the pattern of differentiation had already been induced,

particularly as, in some experiments with both maize and pea roots, tips were cut longitudinally into three slightly unequal pieces, two of which produced whole roots of normal structure. There is also evidence of half root-tips regenerating whole tips. Scheitterer expressed the definite conclusion that the root-tip initial cells—the ' archimeristem '—govern the differentiation of the primary tissues, excepting the formation of root hairs.

In the large adventitious roots of many Monocotyledons, it is particularly evident that no relation exists between the pattern laid down in the root primordium and that already present in the stem to which it has to be connected.

The repetitive nature of the pattern and its inherent stability also become more obvious. The alternation of exarch xylem strands with phloem strands, in a ribbon with definite radial polarity, expresses a harmonious balance of influences and developmental processes. The fundamental uniformity of the root pattern throughout the great majority of vascular plants is further evidence of this inherent stability.

When we turn from large-scale to small-scale roots the number of repetitions is less, but the unit remains the same. The smallest expression of the pattern that is radially symmetrical is a diarch stele, and this is actually the arrangement in the smallest roots of Phanerogams, though monarch roots occur in some Pteridophyta.

In palms, where the roots may be exceptionally large, complications of structure were described by Drabble in 1904 which indicate that there are limits of size beyond which the simple cylinder becomes unstable. In extreme cases a number of separate steles, each similar to a polyarch root stele, are differentiated. These generally show incompleteness on the side towards the centre of the root, the endodermis being absent, or a gap occurring in the ring of vascular strands itself. In other cases there are a number of arcs of the typical root pattern, with incurling ends, or the single cylinder is lobed.

Drabble's observations also show that under certain conditions the pattern can be broken up still further. He figured not only complete diarch, triarch and tetrarch steles, without pith, among the smallest fragments, but also others consisting of one xylem strand and one or two phloem strands, or two xylems and three phloems. A fragment with one xylem and two phloem strands represents the smallest expression of the pattern, which is bilaterally, not radially symmetrical, not a closed cylinder but an open arc.

To turn to the shoot : it will probably be admitted that the shoot apex is a self-determining and dominant centre of development. It controls the polarity of the shoot, and round it the repetitive pattern of leaf primordia unfolds. The apical bud as a whole controls also primary development and secondary growth in the stem below. There is much in the system of relations exhibited which is reminiscent of the part played by organisers in the development of animal embryos.

The influence of the shoot apex may be very extensive. Evidence regarding the sequence of renewal of cambial activity in trees, the downward spread of secondary growth in roots, and the absence of secondary growth in excised roots in culture lend colour to the idea that cambial activity in roots, where present, is initiated by a stimulus from the shoot.

In the determination of primary structure in the stem the leaf primordia

play a predominant part. The number of vascular strands in the leaf base depends partly on hereditary factors, but partly on size. This is particularly clear in Monocotyledons, where the bundles arise in succession, separated by parenchyma, as the new leaf primordium extends round the apex.

Now, in seedlings the conditions are unique. At two ends of a short meristematic axis are two self-determining centres of different kinds in close proximity, two opposite poles, a shoot pole and a root pole, each of which is capable of impressing its own inherent pattern on the meristematic tissues to which it gives rise. Under these conditions we cannot assume that the spheres of influence of each will be sharply defined, nor that they will necessarily be fixed. If the influence of the poles depends on hormones emanating from them, the boundary might well change with changes in relative vigour of the two organising centres, and differ also from one species to another.

It appears reasonable, therefore, as a working hypothesis to interpret the structure of seedlings in the following way :

(1) The cotyledons and, if the plumule is precocious, the plumular primordia, influence the number of procambial strands in the hypocotyl and its diameter growth at an early formative stage. The form of the cotyledons plays a part. Nutritive and other factors subsequently affect the expansion of the hypocotyl and the degree of separation of the bundles by parenchyma.

(2) Differentiation within the strands of procambium is controlled initially by the root apex in the majority of cases, but to a variable distance upwards. The triad represents the smallest unit of the root pattern, existing as a detached arc, whether in the hypocotyl or a dorsiventral cotyledon.

(3) In the upper part of the seedling, sometimes only in the blade of the cotyledon, sometimes also in the petiole, or even lower, the shoot itself holds sway, and in place of a triad is found a single bundle. The intervening region is one of compromise and accommodation between the two patterns.

(4) With increasing activity of the shoot, further development is stimulated, from above downward, in the formation of centrifugal xylem on the inside of the phloem strands. These appear to be the main channels of the basipetal influence. In Dicotyledons the centrifugal xylem is commonly if not generally the result of cambial activity, which ultimately extends down into the root itself.

Where transverse growth in the hypocotyl does not bring about too early a separation of the constituents of the original triad, differentiation of xylem can be seen to proceed, as Bonnier emphasised, from protoxylem towards phloem, whether in triad, collateral bundle, or intermediate arrangements of the two tissues. Chauveaud's ' intermediate xylem ' probably depends in part on displacements resulting from expansion in diameter during vascular differentiation.

One factor in the determination of the relative preponderance of root and shoot is very probably the production of auxin by cotyledons and plumule. It is not without interest therefore that in seedlings of *Cucurbita* (Chauveaud, 1921), where the transition occurs at an exceptionally low level, practically in the root itself, adventitious roots appear very early from the base of the hypocotyl, as might result from an early accumulation of auxin there. It is in any case desirable that a comparative study of auxin concentrations in different parts of seedlings at different phases of development should be undertaken.

There can be no doubt that auxins may be applied with advantage in the experimental analysis of development. S. Williams (1937) has used hetero-auxin very effectively in the study of the rhizophores of *Selaginella*. These arise from meristems found where the stem forks. Normally they grow down to the soil and there produce roots. If, however, the branches are removed early enough the meristem produces a leafy shoot. Application of hetero-auxin paste to the stumps of the branches induces the formation of a positively geotropic rhizophore. The behaviour of the angle meristem therefore depends on the concentration of auxin. Williams describes a case of a positively geotropic shoot which suggests that tropic behaviour and morphology are not completely correlated. It is to be hoped therefore that quantitative experiments, with different concentrations of auxin, will be made, to see how far the rhizophore and the shoot are distinct alternative modes of development : for whereas in Phanerogams auxin determines dormancy of lateral buds and plagiotropism of lateral branches, in *Selaginella* a flow of auxin towards the angle meristems not only determines their polarity but also induces root-like structure, though the root-pattern is not completely realised until new endogenous growing points arise.[2] The example may serve to bring home the fact that the pigeon-holing of organs in morphological categories is but a preliminary step towards the investigation of their fundamental nature.

If the interpretation of seedling structure here outlined be accepted, no evidence of recapitulation is left. Even among zoologists the recapitulation theory is a controversial subject. The case for its application to plants has always been weaker. Even the sequences in vascular structure exhibited by ferns may depend rather on increasing scale than on any recapitulatory change in organisation during the ontogeny of the individual, as Lang pointed out in his address to this Section in 1915. Identity of type at the earlier stages may mean that only the simplest arrangement is possible on so small a scale. Capacity for complexity may be present from the beginning, yet only be gradually revealed as greater scope is provided for its expression. A consideration of the prevalence of a central strand of xylem in slender organs, and in so wide a range of examples as the rhizome of *Rhynia*, the gametophyte of *Psilotum* (Holloway, 1939) and the young endophytic strand of the little mistletoe, *Arceuthobium pusillum* (Thoday and Johnson, 1930), shows that such features may be common to quite unrelated forms, and to organs that are not homologous.

I have emphasised in this address aspects of the study of development in which the activity of the living cells finds obvious expression. I am fully alive to the importance of purely mechanical, physico-chemical and metabolic factors in the development of form and structure, such as have been emphasised by Priestley. Nor do I forget d'Arcy Thompson's *Growth and Form*, which has been a stimulus to many biologists and a delight to all who appreciate boldness in generalisation and elegance in presentation. Yet these deal only with aspects of the larger problem.

We have seen how a substance of known composition, auxin, acts as an agent in the co-ordination of different parts of a plant, but this does not mean

[2] It is conceivable from a causal point of view that a rhizophore might be a sort of chimæra, with a core of root inside a skin of shoot.

that we can explain the activities that are co-ordinated. Great as have been the advances in biochemistry, we are not yet furnished with the means of expressing in physico-chemical terms the delicacy and subtlety of the adjustments exhibited even in plants.

Take, for example, the adhesive disc and haustorium of a mistletoe seedling. This remarkable organ is the result of a series of co-ordinated responses in the growth of the little green meristematic knob from which it arises. Contact pressure leads to one-sided growth, by which it brings itself face downward on to the surface, to which it adheres with the aid of a special viscous material (with the properties of a semi-fluid cuticle). There follows further growth of its now dome-shaped outer shell, the edge of which moves slowly outwards as the area of attachment widens. Under the dome, cells of the lower surface grow out as papillæ, which adhere closely to the epidermis or cork of the host twig. By the outward and upward movement of the growing shell and a contraction of tissue within it, the papillæ are lifted sideways and the adhering outer protective layer is torn up. Then new papillæ fasten themselves to the next cork layer and the tearing process is repeated. In this way several such layers may be picked up till a breach is made in the periderm, giving access to the living tissues within. Through this slit the wedge-shaped haustorium grows.

To think of the inheritance of such an adaptation to the parasitic mode of life merely in terms of chemical substances in chromosomes is at present to underestimate or ignore the complexity of it, for which as yet we have no adequate physico-chemical parallel. It may be less misleading to use the analogy of the inheritance of instinct in animals, which must presumably have a material basis in the genotype, though of what kind we have little conception.

It is strikingly obvious in a specialised organ such as this, where growth is closely and uniquely adjusted in response to a particular environment and in relation to a peculiar, special mode of life, that structure and behaviour are interdependent. There is, however, no logical justification for neglecting to interpret the development of ordinary plant organs on similar lines. The main difference is that the cells respond chiefly to internal influences, though the organ as a whole exhibits tropic curvatures in response to appropriate external stimuli.

Time does not permit me to pursue this line of thought further. I will only refer to the work that has already been done by Schüepp, Priestley, Adriance Foster, Helm, Grégoire, Snow, the veteran Schoute, and many others towards the elucidation in detail of the course of differentiation in the shoot of Dicotyledons and Monocotyledons, from which are gradually emerging a better understanding of the principles of their developmental organisation.

It is one of the privileges accorded to occupants of this chair that they may throw off for a while the inhibitions inseparable from the diligent pursuit of specialised research and express views on broader aspects of Botany. I have taken full advantage of this privilege, even, some may be thinking, to the extent of indulgence in speculation. Yet without imagination our green field would become a valley of dry bones. Imaginative thinking is legitimate when it provides new hypotheses, capable of verification, or stimulates further

investigation. It may also serve a useful purpose if it merely helps to prevent the ossification of theories into dogmas, or exercises a solvent action on views already hardened by long acceptance, like arteries with age.

For wandering in the field I need make no apology. In Section K we have always prided ourselves on being botanists first, specialists second. In this spirit we have resisted the tendency to segregate the physiological from the morphological aspects of our science. I am, I believe, upholding the best traditions of the Section in attempting to promote the fruitful union of these two aspects of the study of structure.

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SECTION K.—BOTANY

COMMUNICATIONS

Dr. G. Bond.—The occurrence of excretion of fixed nitrogen from leguminous root nodules.

A report is presented of investigations on the identity of the factors that promote excretion of fixed nitrogen from leguminous root nodules and the utilisation of the excreted products by associated non-leguminous plants. Particular attention is paid to the importance of light-intensity and the nature of the rooting medium.

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Mr. G. P. Majumdar.—Development and structure of protoxylem vessels in Heracleum.

Protoxylem vessels develop from the procambium, and in leaves also from the cambium. These cells, by their growth in length and volume, develop directly into vessel segments. The spatial adjustment during this period may be brought about by the radial longitudinal division of the adjacent parenchymatous cells, or by their flattening and distortion.

Breaking down of the end-walls takes place very early when the walls are exceedingly thin. The protoplasts, however, do not fuse after this, but remain as 'files of protoplasts.' Pectin films are present in the planes of the transverse walls, and the protoplasts apparently lead an independent career until their disintegration at the completion of lignification.

Secondary thickening of the wall begins only after the vessel segments have attained their definitive size and form. It is preceded by the banding of the peripheral cytoplasm in the same pattern as the subsequent thickenings, of which these bands form the basis. The position and pattern of these bands are associated with the process of pecto-cellulose deposition on the primary wall, and on the pectin films in multiperforate vessel segments. This forms the bases of the bars first described by Rothert in 1899. The bars and their basis are thus different in their chemical nature and method of deposition. After completion of the thickening, which is chemically pecto-cellulose at this stage, lignification proceeds from its central region. Examination under the polarising microscope supports this conclusion.

The same stages have been followed in the differentiation of metaxylem vessels.

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Mr. J. G. Boswell.—Observations on the anaerobic respiration of potato tubers.

Several workers have observed that, when potatoes are transferred from air to nitrogen, the rate of carbon dioxide output rises after a short interval above the 'air line' value. This increase is not maintained over any very long period, and the rate of output subsequently falls and passes below the 'air line.' This phenomenon has, of course, been observed with other bulky tissues, and from experiments with the apple, F. F. Blackman put forward the theory that 'oxidative anabolism' occurred during aerobic respiration.

The work recorded in this paper is an examination of the possible causes of this temporary rise in the carbon dioxide output from the potato tuber. As far as this tissue is concerned the results obtained show that the increased carbon dioxide output on transference from air to nitrogen is due to certain purely chemical changes in the tissue under anaerobic conditions, and is not evidence of the existence during aerobic respiration of oxidative anabolism.

Mr. K. Wilson.—The uptake of water by cut shoots of *Ranunculus fluitans*.

The methods which have been used in the measurement of water uptake by cut shoots of submerged aquatic plants are outlined in relation to the peculiar problems involved, which arise from the specialised plant structure and physical conditions associated with the aquatic habit. A new form of potometer has been designed to overcome these problems.

Observations on water uptake by cut shoots of *Ranunculus fluitans* are described. The rate of water movement, normally small, can be greatly stimulated for a period by the presence of various solutes. This increased rate greatly facilitates observations, and allows changes in the rate of uptake to be observed over short periods of time. It has therefore been made use of for the application of other experimental treatment. It is shown that the removal of the terminal leaf hydathodes greatly reduces water uptake, indicating the part played by these structures in the maintenance of the ' transpiration ' stream, which in the absence of any evaporational mechanism would appear to involve the expenditure of energy by the plant. In this connection some observed effects on water movement of low concentrations of alcohol and cyanide are of interest.

Dr. R. F. Jones.—Effect of salts and other substances on the respiration of *Elodea canadensis*.

The apparatus used in the present work on respiration and the application of Krogh's modification of the Winkler method are briefly described.

Any stimulation of the rate of respiration in the presence of salt solutions is of a temporary nature and the onset of a low respiration rate occurs both in salt solutions and in water only, after a period of continued darkness. The onset of this low rate cannot be obviated by the use of carbohydrate solutions alone.

In the presence of asparagine solution (0·05 per cent.), however, a moderate steady rate may be maintained in darkness over a period of days. This may also occur in an asparagine plus salt solution, when the concentration of the salt is not too high. Further, an increased rate in the presence of glucose cannot be maintained without the additional presence of asparagine (the only organic nitrogenous compound used in this work).

It would appear that the final effect in the production of a low rate of respiration in continued darkness, in the presence or absence of salts or of carbohydrate, is in some way connected with a protoplasmic factor or of some related part of the nitrogen-metabolism.

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Prof. J. Walton.—The Scottish National Forest Park.

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Dr. G. F. Asprey.—Vegetation of the Isle of Canna, Inverness-shire (results of the Glasgow University Expedition to Canna, 1938).

Broadly speaking, the natural vegetation of the island is readily seen to be related to its general topography and climate. The island of Canna consists of a central plateau varying from 100 ft. to 600 ft. high and divided into eastern and western halves by a relatively broad depression extending from the north to the south shore. Except at the latter areas and along the eastern half of the south shore the island is more or less surrounded by vertical cliffs. In these areas the low-lying coastal ledges of varying width and raised beaches lead up to terraced grassy or boulder-strewn slopes and finally to the plateau. As well as experiencing a humid climate, the island is very wind-swept and subject to frequent gales. Three main associations of flowering plants are to be recognised.

Firstly, the maritime associations which, apart from the cliff vegetation, are for the most part restricted to the sheltered harbour between Canna and Sanday. They consist mainly of open communities of shingle plants leading up to a closed *Glyceria-Armeria-Plantago* association. Local variations due to the presence of mud flats and sand are conspicuous features.

Secondly, the *Festuca-Agrostis-Anthoxanthum* association, found on the raised beaches, the coastal ledges and the terraced slopes.

Thirdly, there is the moorland vegetation, dominated for the most part by *Nardus stricta, Scirpus caespitosus* and *Calluna vulgaris*, and confined to the plateau. The moorland is frequently broken up by small comparatively well-drained mounds and attendant wet hollows. By an examination of the communities supported in such localised areas, one is able to obtain some idea of the factors affecting the distribution of the moorland vegetation.

Dr. J. W. Gregor.—Experimental taxonomy; specific and infra-specific categories.

If the number of propositions which can be made concerning classificatory categories is the criterion of a system's naturalness then biologists will agree that the present morphological taxonomic system is the most natural one yet devised. But because its units do not always coincide with variational categories it cannot, in its present form, cope satisfactorily with experimental results which distinguish between degree of population differentiation and kind of differentiation. From the experimental point of view this is a defect which would appear to be inherent in a system in which the units are founded on a complex of attributes irrespective of the variational significance of individual attributes; nevertheless the traditional categories provide a basis for experimental investigations. As an additional focus for evolutionary discussion it would be useful to have a complementary system of taxonomy where the emphasis is transferred to the recording of populations typifying particular kinds of differentiation regardless of the actual degree of aggregate morphological distinctness which they exhibit. That is, from the standpoint of experimental taxonomy, inherent morphological and physiological attributes would not themselves be the determinants of taxonomic status but would act as 'indicators' of the origin (variational category) of population differentiation. In classifying differentiation in the Sea Plantains the following terminology has been used: *coenospecies, ecospecies, cline, geotype* (*intra-* and *extra-clinal*), *ecotype, geoecotype* and *exotype*. Such a classification is in no way antagonistic to traditional taxonomy.

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Dr. D. G. Downie.—The germination and development of *Goodyera repens*.

Seeds of *Goodyera repens* have been germinated aseptically in media containing mineral salts and sugars with and without the addition of plant extracts. Some of the plants so raised have been maintained in culture for two years.

From the roots of the plant growing in pinewoods in the neighbourhood of Aberdeen the fungal symbiont has been isolated and cultured. Successful germination of seed has been obtained in the presence of the symbiont on media with and without the mineral and sugar constituents used in aseptic cultures. The subsequent growth of infected seedlings far surpasses that of the aseptic seedlings.

Seedlings are of rare occurrence in nature and are almost invariably associated with mature plant colonies. Germination experiments on field plots in pinewoods and on pine needle litter brought into the laboratory have so far given negative results.

The entrance of the symbiont into the host is not restricted to the early stages of

germination. Aseptic seedlings of varying age have become readily infected when introduced into a suitable culture along with the symbiont.

Recently, a second symbiont has been found associated with the plant.

Mr. E. G. Davies.—The post-glacial history of Blaen Brefi.

Blaen Brefi is a bog situated 22 miles south-east of Aberystwyth, its major axis lying north-west to south-east. It occupies a shallow pocket between two lines of hills, themselves covered with *Molinia* pasture, at the head waters of the Afon Brefi and Pysgotwr Fawr, at a height of approximately 1,400 ft.

The central axis of the bog is occupied by an Erosion Complex, followed on the north-east and the west by a Scirpetum. Near the foothills the Scirpetum is replaced by a Juncetum, which latter merges gradually into the *Molinia* pasture.

Borings show that the base is occupied by boulder clay. A comparison is made between the stratigraphy of Blaen Brefi and that of Rhos Rhudd and other Cardiganshire bogs. Certain deductions regarding the post-glacial history of the bog are possible, and the current development of the present formation is correlated with that of other hill bogs.

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Miss E. M. Canton.—Observations on the autecology of *Rhynchospora alba*.

Rhyncospora alba Vahl (Cyperaceæ), a coloniser of peat bogs, reproduces vegetatively by the production of bulbils of two types :

(*a*) *Lateral* bulbils formed in leaf axils and becoming detached from the parent plant.

(*b*) *Terminal* bulbils which remain attached to the parent plant.

In general, a lateral bulbil gives rise to a flowering plant, while the terminal type will again produce a terminal bulbil and thus no inflorescence.

Investigation shows that under conditions of deficient aeration and water content, over 50 per cent. of the bulbils formed are terminal. By the addition of nutrient solution to bog water, terminal bulbils can be induced to flower.

Plants of *Rhyncospora alba* colonising peat are considerably smaller than those growing with living *Sphagnum.*

Germination commences in early April. Under cultural conditions, freezing was found to be necessary before it took place.

The formation of the terminal bulbil plays a great part in the development and maturation of the seedling plant.

The growth of the species is associated with the presence of mycorrhiza, septate hyphæ being especially abundant in the tissues of root and seed coat.

High percentages of bulbils are destroyed by birds and wireworms. Ovaries have been seen attacked by the ' smut ' fungus *Cintractia Montagnei.*

Mr. C. Leighton Hare.—Some observations on *Eriocaulon septangulare* With.

Eriocaulon septangulare is a small aquatic Angiosperm, the sole British representative of a family widespread in tropical and sub-tropical regions.

It is associated with some six or seven other plants, of various affinities, to form the small group commonly referred to as the North American element in the British flora.

The plant does not occur on the continent of Europe and as a British plant is found only in the west of Ireland and in the Scottish islands of Skye and Coll.

Its peculiar distribution raises a number of problems of considerable interest. In the hope of shedding some light on these, an investigation of its structure, biology

and ecology has been carried out. In the course of this work an attempt has been made to determine the climatic and edaphic preferences of the plant and, by following its life history, to gain an insight into those biological processes which are clearly linked up with its means of propagation and dispersal, and its ability to colonise fresh areas.

A brief account of some of the results obtained is presented, and an attempt is then made to apply them to a clearer understanding of the peculiarities of the distribution of the plant in the British Isles.

Sir Frank Stockdale, K.C.M.G., C.B.E.—The application of economic botany in the tropics.

Reference is made to the distribution and establishment of tropical economic crop plants and to the parts played in the past by botanic gardens, missions and private individuals.

The plantation rubber industry of the East has resulted from seeds collected from the Amazon jungles, cacao in West Africa from introductions from tropical America, the Eastern palm oil industry from plants derived from West Africa. The sugar-cane and bananas of the West Indies were of old-world origin. Selection and crop improvement work has been necessary.

The production of types resistant to various pests and diseases has been necessary and has still to be continued.

Work being done for the sugar-cane, rubber, cacao, cotton, banana, rice, coffee and sisal industries is described. The results obtained so far from selection and plant breeding are mentioned and the important advances made from interspecific crosses referred to.

Special assistance has been rendered by the plant physiologist in the study of the die-back of coffee and in regard to the problem of shade. The value of the ecologist in problems of land utilisation and soil conservation is recognised and the importance of using vegetal cover in soil erosion control measures is emphasised.

Plant improvement is relative to environment and sound advance is unlikely to be achieved if this is not recognised. Agricultural methods to suit the environment and to ensure soil conservation with the maintenance of soil fertility should be developed *pari passu* with crop improvement.

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Joint Discussion with Department K* (Forestry) on Seed provenance, local races and breeding of forest trees (in Section K room).

Mr. T. Thomson.—Introduction.

Dr. R. Melville.—The distribution of British species and local races of elm.

With the exception of the Wych Elm, *Ulmus glabra* Huds., and the English Elm, *U. procera* Salisb., the British elm species are comparatively restricted in their distribution. The Wych Elm occurs from the south coast of England to the north of Scotland.

The English Elm is widespread and common throughout southern England, but thins out in Yorkshire and may be only planted in Scotland.

The elms with a more limited distribution include the Cornish Elm, *U. stricta* Lindley, the Plot Elm, *U. Plotii* Druce, the Smooth-leaved Elm, *U. carpinifolia* Gleditsch (*U. nitens* Moench), the Sowerby Elm, *U. nitens* var. *Sowerbyi* Moss, and the East Anglian Elm, *U. diversifolia* Melville. The Cornish Elm is common in Cornwall and Devon, but rapidly thins out eastwards into Dorset and is only occasionally planted elsewhere. The Jersey or Wheatley Elm, *U. stricta* var.

sarniensis (Loud.) Moss, said to be native to the Channel Islands, is widely planted as a street tree. Another variety, the Goodyer Elm, *U. stricta* var. *Goodyeri* Melville, is confined to the coastal plain to the south of the New Forest in Hampshire. The Plot Elm is concentrated mainly in the Trent Valley and certain adjacent valleys with outlying colonies at Banbury and Cambridge. It favours deep moist soils. *U. carpinifolia* occurs scattered over the Midlands and East Anglia, while the Sowerby Elm extends in a broad band across the Midlands into East Anglia. The East Anglian Elm is common on the coastal plain of Suffolk to the north of Ipswich and scattered elsewhere in East Anglia. In addition to the species mentioned there are a great many hybrids, some of which, especially in parts of Essex, form local races inhabiting particular river valleys.

The elms differ greatly in silvicultural value. *U. glabra* is the most common of those used for coppice, but it tends to branch near the base, and is the most susceptible to Dutch Elm disease. The Cornish and Jersey Elms and *U. Plotii* are trees of good form, most of the timber being formed in the trunk.

Dr. M. A. P. Madge.—Zoospore formation in a species of Stigeoclonium.

A species of *Stigeoclonium*, not yet identified, has been grown in culture for two years at Royal Holloway College and can generally be induced to form zoospores by a simple method of re-inoculation. During the twenty-four hours prior to zoospore formation, the walls of the cells of the erect filaments undergo a cell division which results in the formation of a transverse wall. This wall remains thin in those filaments which are about to form zoospores and does not constrict the filaments as much as the other cross walls do, so that the cells appear to be arranged in distinct pairs. A single zoospore is formed in each cell. The rounding off of the protoplast to form the zoospore is accompanied by a large increase in the size of the cells of the filament, which elongate very rapidly just as the protoplast assumes a motile condition. The quadri-flagellate zoospore swims about inside the cell, hitting the wall which stretches still more. This bombardment frequently results in the breaking down of the thin transverse wall, so that two zoospores may be swimming inside a common boundary. The movements continue until the cell walls give way and the zoospores escape. After this has happened, nothing is left of the filament except the basal cells still attached to the prostrate system and a few free floating cells from the apex.

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Miss E. M. Blackwell.—A life-cycle of *Blastocladia Pringsheimii* Reinsch.

At a corresponding session of Section K last year (*British Association Report, Cambridge*, 1938) Dr. Ralph Emerson announced that a complete life-cycle had not yet been described in any species of *Blastocladia.*

During the months that have elapsed it has been clearly demonstrated in the Botanical Laboratory of Royal Holloway College that in *Blastocladia Pringsheimii* the life-cycle may be of the simplest form : both thin-walled sporangia and thick-walled resistant sporangia giving swarmers that do not fuse but germinate immediately to give plants like the ones that gave the resistant sporangia.

Dr. Emerson, who became interested in the work in progress, gave the final proof by isolating the swarmers as they were liberated from a resistant sporangium and germinating them in pure culture. The plants that developed from them resembled in all respects the original plants and liberated, within two days, swarmers that did not fuse but germinated and gave rise to plants again like the original ones.

The resistant sporangia of *Blastocladia* do not readily germinate. The only published record is a statement by von Minden (1916) that once on soaking old and dry sporangia he observed slits in the outer wall, but not the liberation of swarmers.

Dr. Emerson has an unpublished description of how in 1937 he isolated swarmers that had undoubtedly come from old, dried resistant sporangia, and germinated them in pure culture.

Although it is impossible to state the precise conditions for successful germination, there is no doubt that it is encouraged by :

(*a*) a period of rest of not less than four months, during which period the resistant sporangia may be kept in water or stored dry ;
(*b*) alternating periods of wet and dry conditions ;
(*c*) alternating heat and cold.

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Miss G. M. Waterhouse.—A species related to *Pleolpidium inflatum* Butler.

A chytridiaceous parasite was found infecting a species of *Phytophthora* growing among water moulds from the Hogsmill river, Surrey. It was interesting in resembling very closely *Pleolpidium inflatum* Butler, which has never been recorded in the British Isles nor been described since the original account (1907) ; *P. inflatum* was originally found parasitising *Pythium intermedium* in the soil. A description of the stages in the life history is now given, but resting spores were not found nor was it possible to test its pathogenicity for *P. intermedium* before it disappeared, although cross inoculation experiments with the original host and with another aquatic *Phytophthora* (= ? *Pythiomorpha gonapodyides*) were carried out in the laboratory (Royal Holloway College) and were successful. The paper directs attention to the present dissatisfaction with the nomenclature of the genus *Pleolpidium* and to the status of *P. inflatum* in particular. Any fresh appearances of these parasites would be helpful in settling the problem.

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Miss M. V. Thompson.—The life-history of a water-mould allied to *Pythiomorpha gonapodyides* Petersen.

A water mould with proliferating sporangia was collected by Dr. M. P. Hall (Mrs. Topping) on apples as bait, in a pond near Manchester, and identified by her as *Pythiomorpha gonapodyides* Petersen. She obtained it in pure culture and sent it to the Botanical Laboratory of Royal Holloway College, where it has been investigated. As the fungus did not always agree in its behaviour with the reports of *Pythiomorpha gonapodyides* by various workers, e.g. oogonia and antheridia were produced in abundance, it was sent to Mr. Ashby, Director of the Imperial Mycological Institute. He identified it as *Phytophthora megasperma* Drechsler.

Proliferation of the sporangium was made the diagnostic feature of a new genus *Pythiomorpha* by Petersen in 1909. Since then several species of *Phytophthora* with proliferating sporangia have been isolated, and Buisman in 1927 came to the conclusion that Petersen's fungus should be re-named *Phytophthora gonapodyides*. This was accepted by Fitzpatrick 1930, Drechsler 1930 and Lund 1934. Other workers (Kanouse 1927, Ito and Nagai 1931, Cejp 1932, Forbes 1935, Sparrow 1936 and Höhnk 1936) have since published work on *Pythiomorpha gonapodyides*. Indeed, Ito and Nagai, and Höhnk have recently made new species of the genus *Pythiomorpha*. It is not at all certain that the strains that have been isolated and called *Pythiomorpha gonapodyides* are all one and the same. They should perhaps be assigned to existing species of *Phytophthora*, that have been found occurring in water and bearing proliferating sporangia. This would account for the discrepancies in the existing literature on *Pythiomorpha gonapodyides*.

There is however no record of species of *Phytophthora* as water moulds beyond the note that Bewley and Buddin in 1921 isolated *P. parasitica* and *P. cryptogea* from glasshouse water supplies.

Petersen's description of his strain, and his diagram of the sporangia, are typically

those of a *Phytophthora* as we now know it. The present report attempts to add support to Buisman's original theory, that in the light of modern knowledge of the genus *Phytophthora* the species of *Pythiomorpha* should be included in this group.

Mr. J. Carrick.—Some aspects of the physiology of a new species of Stemphylium.

A new species of *Stemphylium* (Wallroth) has been found growing on sail-cloth and causing extensive damage to tents in this country and in Australia. Since the cloth is heavily impregnated with fungicides during proofing, the vigorous growth of the fungus is the more remarkable, and it therefore presents a pretty problem in control. An investigation of its growth and reproduction under cultural conditions has been begun, and those aspects deemed worthy of particular note are recorded in this paper.

The general physiological principles controlling growth and reproduction were examined in water cultures containing varying concentrations of the nutrient substances. It was evident that a certain amount of toxicity occurred, both in regard to the formation of mycelium and also the production of spores, in the presence of ammonium nitrate. Different nitrogenous substances in combination with several carbohydrates were used as a basis for agar cultures, and from these it would seem that the fungus prefers its nitrogen in an organic form. The reaction of the fungus to change in pH and temperature, and in presence of heavy metals, has also been studied.

* * *

Prof. J. Doyle.—Further observations on pollination in the Pinaceae.

The structure of the ovule in relation to the reception and subsequent behaviour of the pollen is described in *Abies*, *Picea* (including reference to unusual features in the genus as in *P. orientalis*), and *Tsuga Pattoniana*. This latter species, differing from the *Tsuga* spp., already elsewhere described, in the possession of winged pollen, differs also in ovular structure. *Picea orientalis* differs from other spruces in the young cones being inverted at pollination, instead of being erect when young and becoming pendent later. An interesting variation in the pollination mechanism is shown in relation to this.

Dr. J. Burtt Davy.—The geographical distribution of some African groups of woody plants.

An analysis of the distribution of African dicotyledonous families and genera shows some striking features of distribution, among which the following are of particular interest :

(1) The complete absence from Africa south of the Mediterranean zone of certain widely distributed north temperate families.

(2) The relatively poor representation south of the Sahara of the characteristic warm temperate north African flora.

(3) The occurrence of a definite north temperate zone element in the montane rain-forest of East Africa, extending from Abyssinia to Table Mountain.

(4) The difference in composition of the East Tropical and West Tropical African floras.

(5) The absence from East Africa of certain Afro-Asiatic genera which occur in West Africa.

(6) The absence from continental tropical Africa of a large part of the Madagascar-South African element.

(7) An apparent distinction between the Afro-Ceylon-Indian element and the Afro-Malayan-Australasian element.

(8) The occurrence in West Tropical Africa of isolated members of Tropical American genera and families.

Suggestions are offered to account for these features in the distribution.

* * *

Mr. T. K. T. Jacob.—Cytological evolution in Sesbania.

* * *

Mr. S. M. Sikka.—Organisation of the nucleolus in Narcissus.

* * *

Dr. N. W. Radforth.—The affinities of the fossil schizæaceous ferns.

With the application of the transfer and oxidation methods to the carbonaceous compressions of *Dactylotheca Sturi* and *Senftenbergia pennaeformis*, structural details of these plants may be conveniently examined. In a detailed study of their sporangia, the mechanism for dehiscence is clearly revealed. Contrary to previous belief, sporangia of *D. Sturi* bear annuli which consist of an oblique apical band of thick-walled cells. Sporangia of *S. pennaeformis* are also annulate, but the annuli, although resembling those of *D. Sturi* as to position and type, differ in detail of structure.

Spores of both these plants, preserved in different developmental stages, are extracted, and their structure and ornamentation compared.

Dactylotheca Sturi, having annulate sporangia, becomes a member of genus *Senftenbergia* although remaining specifically distinct. The comparison of the sporangia and spores of both plants with those of *Senftenbergia plumosa*, and the living schizæaceous types, particularly *Aneimia*, points to a series in which progressive structural changes have occurred in connection with the annulus, and in which spore output has diminished. The sporangia of *S. Sturi* are the most primitive in structure, and those of *S. pennaeformis* are the most specialised. With this progressive specialisation, the dehiscence mechanism appears to have become correspondingly more efficient.

Exhibits.

Dr. G. Asprey.—Vegetation of the Isle of Canna.

Miss E. M. Canton.—*Rhynchospora alba*.

Mr. J. Carrick.—A new species of Stemphylium.

Miss A. J. Davey.—Morphology (including contractile roots) in the genus Oxalis.

Dr. D. G. Downie.—*Goodyera repens*.

Mr. C. Leighton Hare.—*Eriocaulon septangulare*.

Mr. J. B. Jones and Mr. E. G. Davies.—The post-glacial history of Blaen Brefi.

Mr. G. P. Majumdar.—The protoxylem of Heracleum.

Dr. R. Melville.—Nothoclines in *Ulmus*.

Prof. E. G. Pringsheim.—Cultures of algæ.

Prof. J. Walton.—Lower Carboniferous plants from the Kilpatrick Hills, Dumbartonshire.

Miss I. M. Hayward.—Coloured impressions of Tweeddale and the Borders (Film).

The film is a survey of the Scottish Borderland with emphasis on the beauty and life of the countryside, including studies of several of the fine gardens in the locality. The historical side of the district is illustrated by impressions of famous abbeys and romantic houses.

DEPARTMENT K*.—FORESTRY

COMMUNICATIONS

Capt. G. I. Campbell, Yr. of Succoth (Chairman).—Forestry in Scotland.

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Discussion on the Larches.

Dr. S. E. Wilson.—The qualities and uses of larch timbers.

Dr. M. L. Anderson.—The silviculture of the larches.

Consideration is given only to two of the species of larch, namely, the European larch and the Japanese larch.

After a brief reference to the utilitarian aspect of growing larches on a large scale, the most important silvicultural characteristics of the European larch are dealt with in some detail. Passing reference is made to the existence of races within the species. The place of the European larch in our silviculture is then discussed on the basis of the particular requirements and qualities of the tree. Its cultivation as a main crop tree, as a nurse tree and as a soil-improving species is considered and an attempt is made to distinguish the sites or soil-types where it can be satisfactorily utilised for those various purposes.

The silvicultural characteristics of the Japanese larch are then reviewed, with special emphasis upon those points in respect of which that species differs from European larch. Circumstances under which the Japanese larch is to be preferred to the European species are described. Finally, there are some observations on the possibilities of using methods of natural regeneration for these species.

Mr. J. A. B. Macdonald.—Larches on peat and poor *Calluna* types.

Data on which the paper is based have been obtained mainly from recent assessments of experiments established by the Forestry Commission on these poor land types in Scotland between 1924 and 1936. So far as early development is concerned, the Japanese and hybrid species are most encouraging, but on these difficult ground types an initial dressing of phosphate is as necessary as, if not more necessary than, special pre-planting treatment such as turfing or ploughing.

Naturally, with such comparatively recent introductions, little material is available for a comparison of the three larches at more advanced stages of development. To begin with, as is not uncommon with new species, they were planted only on very favourable sites. References are made to instances of larch growth encountered during silvicultural studies of plantations on difficult sites.

Mr. J. M. Murray.—The hybrid larch.

Mr. Fraser Story.—The Sudeten larch.

Mr. W. R. Day.—The diseases of the larch.

There are many factors, physical and biotic, responsible for disease in European larch in Britain. The more fundamental of these are probably physical; that is they are factors of climate or of soil which basically determine the type of habitat in which the tree has to be grown. The more complete failures of European larch have thus probably been due to a failure, on one side, to appreciate the fundamental requirements of the tree which may vary slightly according to the climatic variety, and on the other to appreciate with sufficient accuracy the physical character of the habitat into which it has been introduced. Troubles arising from fungus parasites or insect pests are of less importance. So also is the silvicultural treatment of the plantations, although this may also be an important factor in predisposing to disease.

* * *

Dr. A. B. Stewart.—The maintenance and improvement of soil fertility in nurseries.

The natural reserves of plant food materials may differ enormously from soil to soil, but unfortunately in none of our soils are these reserves inexhaustible. If fertility is to be maintained, additions of nutrients in suitable form are necessary from time to time in order to counteract losses such as removal of nutrients in seedlings and transplants, soil drainage losses, which may be heavy, particularly in the lighter soil types suitable for nurseries, and reversion of soluble food materials such as phosphate to insoluble or unavailable forms in the soil.

In determining the treatment to be given to a nursery soil factors such as the following are considered : (*a*) species to be grown, (*b*) previous treatment and cropping, and (*c*) properties of the soil, e.g. texture, organic matter, acidity, supplies of calcium, phosphorus, potassium, nitrogen, etc., already present. The necessity for taking full account of the properties of the individual soil is stressed and the value of soil analyses pointed out. The results of analysis of a given soil, especially when correlated with nursery trials on a soil of similar type, provide a most useful means of determining the requirements of the soil.

* * *

Mr. J. A. B. Macdonald.—Experiments on season of sowing, weed control and some other nursery problems.

Fortnightly sowings were carried out with three tree species in seven Scottish nurseries during the spring seasons of 1935, 1936 and 1937, and also in the autumn of 1935 and 1936. The results which have now been worked up and summarised are discussed.

Methods of controlling weed growth on seedbeds either by scorching or by application of chemicals have been the subject of experiments for at least ten years. Gradually, treatments have been readjusted in the light of earlier results. The most recent experiments have been very successful.

Perhaps no innovation has done more to improve the outturn of seedlings—especially of Sitka spruce—than the practice of covering seedbeds after sowing with a clean, clay and silt-free sand, grit or even heavier material such as road-metal chips. Some figures from the numerous experiments incorporating these coverings are submitted, and the most recent developments mentioned.

Among other experiments, some which showed the possibility of sowing in wet weather or, by soaking, during a drought, are mentioned and their significance stressed.

* * *

Mr. R. Davey.—Forestry for game.

Amenity, profitable forestry and sport, with the accent on sport, were the keynotes of two working plans recently prepared for two estates (350 and 277 acres of woodland), typical of many in the country, where woods are neglected because forestry is supposed to spell ruination for game. The opposite and equally fallacious view is that forestry cannot be undertaken with any prospect of success or profit if game considerations have to be taken into account.

So far as finance is concerned the effect of planning the woods for sport was in one case a loss of 17½ per cent. and in the other of less than 10 per cent. of plantable area. All the coverts were planned for planting with profitable and suitable light-demanding species, and will be managed entirely with forestry considerations in mind.

The species, mixtures, rotations and management of coverts and other areas, and the design and arrangement of rides, and the siting of flushing points and rises were worked out in detail for two different types of woodland estate.

The system was planned to achieve orderly management of coverts and flushing points by the woodland staff, in place of the far too common haphazard methods of the average keeper.

REPORTS OF RESEARCH COMMITTEES

SECTIONS D, H, and K

In accordance with previous practice, the reports of certain Research Committees will continue to be recorded in print. The full list of Research Committees appointed for the year 1939–40 will appear in a subsequent issue.

SECTION D, &c.

THE ZOOLOGICAL RECORD

REPORT of the COMMITTEE appointed to co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the *Zoological Record* (Sir SIDNEY F. HARMER, Chairman ; Dr. W. T. CALMAN, Secretary ; Prof. E. S. GOODRICH, Prof. D. M. S. WATSON).

THE grant of £50 was paid over to the Zoological Society on May 16, 1939, as a contribution towards the cost of preparing and publishing Vol. LXXIV of the *Zoological Record* for 1937.

The report of the Council of the Zoological Society for 1938 shows that the cost of the *Record* continues to increase, and its continuation is only made possible by the support received from contributing institutions and individuals. The Committee accordingly asks for reappointment, with the renewal of the grant of £50.

ARTEMIA SALINA

REPORT of the COMMITTEE appointed to investigate the progressive adaptation to new conditions in Artemia salina (Prof. R. A. FISHER, F.R.S., Chairman ; Dr. A. C. FABERGÉ, Secretary ; Dr. F. GROSS, Mr. A. G. LOWNDES, Dr. K. MATHER, Dr. E. S. RUSSELL, O.B.E., Prof. D. M. S. WATSON, F.R.S.).

A DISCUSSION of the problem investigated, together with a programme of these experiments, was given in the report of this Committee for the year 1937, presented at the Nottingham Meeting of the British Association. Work in the year 1938–39 has followed this programme.

The major part of the testing foreseen in that programme, at least as far as the number of nauplii tested is concerned, was already accomplished before this year. It was planned to test about 1,000 nauplii in each of six generations in seven lines. With the stronger lines, such as C_6, C_7, $C_6 \times C_7$, this has now been done. Much difficulty was, however, experienced in getting the less prolific lines, such as C_2 to breed, and in them the testing programme is still far from completion. It is for this reason that the total number of nauplii tested during 1938–39, 9,024, is only about a quarter of the number tested in the previous year. The amount of work involved in propagating these relatively infertile strains has, nevertheless, been considerable. The testing and breeding of the material has been carried out, as in previous years, by Miss S. B. North.

The distribution of tested nauplii among the six generations and the seven lines used this year is shown in Table 1. All these data are supplementary to those of previous years.

It was pointed out in the three previous reports that the main source of error in these experiments is the variation in resistance to poison of different broods from the

same mating. In last year's report it was also described how a system of controls was used in an attempt to avoid this source of discrepancy, and how these controls had proved ineffective. This year attempts were made to discover the environmental factor responsible for variation, with a view to controlling it.

At the beginning of this investigation Dr. Gross had satisfied himself that the age of broods, within reasonable limits, had no appreciable effect on resistance to arsenic. Nevertheless, the possibility was not excluded that the size of nauplii

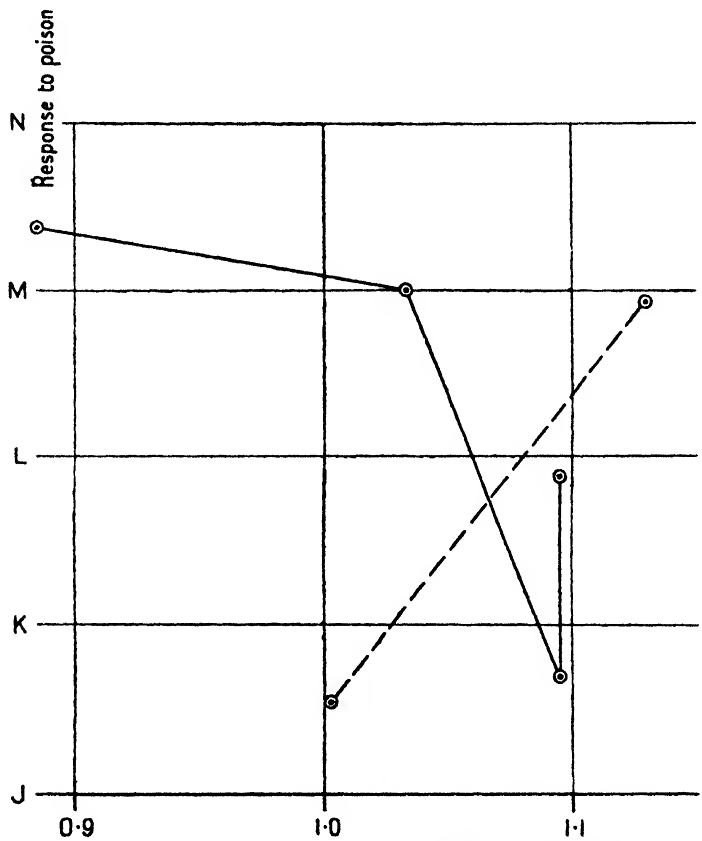

FIG. 1.

would be related to resistance. To test this, nauplii from controls were preserved in formalin, and their length measured by means of a projecting microscope. An analysis of variance on these measurements shows that variation *between broods within matings* is significantly greater than that *within broods*. Nevertheless, there is no appreciable correlation between size and resistance to poison. To illustrate this, data from two matings which produced two and four broods respectively are plotted in Fig. 1. The mean length is plotted against the 50 per cent. death point, the scale of the latter being in terms of the strength of poison solution.

In the usual testing procedure the strength Chlamydomonas culture used as food is standardised by means of a colorimeter. It is possible that some variations occur in this measurement, and tests were therefore made to determine the effect of food strength. *Chlamydomonas* culture was used at half and at twice the normal strength, a

difference much greater than can arise in the standard testing. Food strength has no marked effect on resistance ; as an example the data from four large broods tested in two strengths of food are given in Table 2.

Although the room in which Artemia are tested is thermostatically controlled, some variations in temperature do occur. Tests were made to determine if these fluctuations have any effect on resistance to poison. No effect whatever was found.

It is difficult to think of any other controllable external factors which could be responsible for the large discrepancies in resistance. The conclusion would seem to be that resistance to poison is determined by some conditions of the micro-environment which are difficult to control experimentally.

Since the use of controls is ineffective in reducing variability, the complicated statistical treatment devised to take controls into account is now unnecessary. Consequently, in the later computations we have reverted to the simpler method which ignores natural death rate. By this means arithmetical labour is much reduced, and it is hoped the statistical analysis will soon keep pace with the experiments.

The data obtained during 1938–39 are given in Tables 4–9. In Table 3 are given the strengths of sodium arsenite corresponding to the letters used in the other tables.

The Committee asks to be reappointed with a grant of £20.

TABLE 1.

	C_2		C_3		C_4		C_7		$C_6 \times C_7$		$C_7 \times C_6$	
	T.	S.	T.	S.	T.	S.	T.	S.	T.	S.	T.	S.
S_0 .	250	194	—	—	—	—	—	—	—	—	—	—
S_1 .	512	320	115	55	—	—	—	—	—	—	—	—
S_2 .	458	242	—	—	—	—	—	—	—	—	616	335
S_3 .	101	31	22	12	139	67	646	347	—	—	320	196
S_4 .	103	54	64	30	602	261	60	49	723	415	1,339	630
S_5 .	—	—	243	75	—	—	—	—	967	590	1,744	858
Totals	1,424	841	444	172	741	328	706	396	1,690	1,005	4,019	2,019

T. = tested. S. = survived.

TABLE 2.

Broods.	A		B		C		D	
Food strength . . .	$\frac{1}{2}$	2	$\frac{1}{2}$	2	$\frac{1}{2}$	2	$\frac{1}{2}$	2
Tested . . .	96	96	63	63	70	70	112	112
Survived . . .	45	38	24	25	18	30	57	48

TABLE 3.

Letter designating poison solution	Strength of solution of sodium arsenite, expressed as normality
G	0·004529
H	0·005000
I	0·005520
J	0·006095
K	0·006729
L	0·007430
M	0·008203
N	0·009057
O	0·010000
P	0·011040

TABLE 4.—Line C_2.

	S_0		S_1		S_2		S_3		S_4	
	T.	S.	T.	S.	T.	S.	T.	S.	T.	S.
I . .	11	10	20	18	—	—	—	—	—	—
J . .	11	10	30	24	38	26	—	—	—	—
K . .	39	35	30	22	58	34	—	—	—	—
L . .	39	35	46	29	58	26	11	9	8	8
M . .	50	35	68	38	58	31	11	4	19	14
N . .	42	15	105	46	58	17	22	11	19	10
O . .	—	—	70	12	58	3	25	0	19	6
P . .	—	—	—	—	20	0	11	0	19	5
Control 1 .	45	43	78	71	58	57	21	7	19	11
Control 2 .	13	11	65	60	52	48	—	—	—	—

TABLE 5.—Line C_3.

	S_1		S_3		S_4		S_5	
	T.	S.	T.	S.	T.	S.	T.	S.
G . .	15	6	—	—	—	—	—	—
H . .	14	2	—	—	—	—	—	—
I . .	14	7	—	—	—	—	5	4
J . .	14	7	—	—	—	—	20	9
K . .	14	5	—	—	—	—	38	4
L . .	14	1	7	6	18	7	56	6
M . .	—	—	7	4	11	1	38	7
N . .	—	—	7	1	11	0	28	2
Control 1 .	15	14	1	1	24	22	58	43
Control 2 .	15	13	—	—	—	—	—	—

TABLE 6.—Line C_4.

	S_3		S_4	
	T.	S.	T.	S.
G	11	0	35	10
H	11	6	35	13
I	11	7	76	44
J	21	12	73	33
K	34	15	81	37
L	10	2	82	22
M	10	0	38	1
N	—	—	38	0
Control 1 . .	21	16	76	56
Control 2 . .	10	9	68	45

TABLE 7.—Line C_7.

	S_3		S_4	
	T.	S.	T.	S.
H	43	31	—	—
I	79	50	—	—
J	89	61	10	10
K	89	57	10	10
L	89	32	10	10
M	89	21	10	8
N	31	0	10	2
Control 1 . .	100	79	10	9
Control 2 . .	37	16	—	—

TABLE 8.—Line $C_6 \times C_7$.

	S_4		S_5	
	T.	S.	T.	S.
H	88	55	—	—
I	89	59	76	73
J	93	54	76	69
K	93	49	90	69
L	93	35	125	69
M	93	6	162	70
N	—	—	182	13
Control 1 . .	93	83	170	160
Control 2 . .	81	74	86	67

TABLE 9.—Line $C_7 \times C_6$.

	S_2		S_3		S_4		S_5	
	T.	S.	T.	S.	T.	S.	T.	S.
H . .	59	30	—	—	—	—	—	—
I . .	69	41	39	29	143	97	101	78
J . .	69	38	39	30	162	89	162	109
K . .	79	37	39	28	162	65	210	142
L . .	87	33	39	26	178	57	267	121
M . .	87	29	52	23	178	31	267	89
N . .	10	1	45	8	196	27	241	77
P . .	—	—	—	—	—	—	130	18
Control 1 .	86	72	60	47	190	166	264	184
Control 2 .	70	54	7	5	130	98	102	40

PLYMOUTH LABORATORY.

REPORT of the COMMITTEE appointed to nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth (Dr. W. T. Calman, C.B., F.R.S., Chairman and Secretary ; Prof. H. Munro Fox, F.R.S., Dr. J. S. Huxley, F.R.S., Prof. H. G. Jackson, Prof. C. M. Yonge).

The grant of £50 was paid over to the Marine Biological Association on February 20, 1939.

Miss M. J. Dibb reports that during her occupation of the Association's table at the Laboratory in July 1938 she studied the life histories of certain sporozoan parasites of marine 'worms.' Drawings and measurements were made from living specimens, and material was fixed for later investigation.

Dr. Margaret W. Jepps, who occupied the table from October 1 to December 31, 1938, was further nominated to hold it from January 1 to March 31, 1939. She reports that she has made good progress with her work on the life history of *Polystomella*. She has been successful in rearing the asexually-produced young in cultures, and has studied what is generally believed to be the sexual phase of the life-cycle. A good deal of time has been spent in trying various methods of fixation, and much material has been preserved for later study.

Prof. H. Graham Cannon, F.R.S., has resigned from the Committee.

The Committee asks for reappointment, with renewal of the grant of £50.

WICKEN FEN

REPORT of COMMITTEE appointed to assist in the preservation of Wicken Fen (Prof. F. T. Brooks, F.R.S., Chairman ; Dr. H. Godwin, Secretary ; Prof. F. Balfour-Browne, Dr. H. C. Darby, Prof. J. Stanley Gardiner, F.R.S., Mr. J. A. Steers, Dr. W. H. Thorpe, Dr. D. H. Valentine).

Two major problems have always presented themselves most urgently to the biologists interested in maintaining in Wicken Fen communities of the fauna and flora typical of the old conditions of undrained fenland. These are both the result of the unceasing progress of development and natural succession, which causes on the one hand a rising ground-level, and on the other continual invasion by species of drier habitats at the expense of the paludal or aquatic species.

The grant of £50 has been expended in combating these two effects separately. £25 has been contributed towards the cost of excavating a large shallow mere, horse-shoe shaped, and about half an acre in extent. This mere will make good, to some extent, the serious and growing lack in the Fen of areas of shallow open water, such as the deeper reed swamp and fen bordering open water. It should prove a refuge for a great many species of plants and animals (especially water birds) whose habitats on the Fen were becoming very restricted. It will also afford an excellent opportunity for observing the mechanism of invasion and establishment of the reed-swamp communities.

The remaining £25 has been expanded in carrying out the clearance from several acres of sedge-fen (Cladietum and Cladio-Molinietum) of the very dense bush growth which had invaded it and which, in the course of twenty or thirty years would certainly have led to a complete and irreversible extinction of this area of the most characteristic of the fen communities. It should be said that the colonising bushes (*Frangula alnus* and *Rhamnus catharticus*) are being left in certain observed areas to establish the natural fen woodland, but it is imperative that their extension should

be severely restricted if the Fen is to remain an effective sanctuary for the old fenland species and communities, and an area in which scientific research upon fenland species of plants and animals can be profitably maintained.

The Committee is satisfied that the expenditure of the grant has been of considerable benefit to scientific work.

The Committee asks for reappointment with a grant of £50 for 1939–40.

FRESHWATER BIOLOGICAL STATION, WINDERMERE

REPORT of the COMMITTEE appointed to aid competent investigators to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Westmorland (Prof. F. E. Fritsch, F.R.S., Chairman ; Dr. E. B. Worthington, Secretary ; Prof. P. A. Buxton, Miss P. M. Jenkin, Dr. C. H. O'Donoghue, Prof. W. H. Pearsall).

During the past year the British Association's table at Wray Castle has been occupied by Miss Winifred Pennington of the Botanical Department, Reading University. She has worked on cores raised from the bottom deposits of Windermere, especially with a view to following through the succession of diatoms and other organic remains which are to be found in various layers of the deposits. The summary of her findings, extracted from a detailed progress report, have been filed for reference. The tenure of the table during the previous year by Mr. G. H. Wailes has resulted in three publications on the microplankton of Windermere in the *Ann. & Mag. of Nat. Hist.* : ser. 11, **1** : 496–7, 553–5 ; **3** : 401–14.

SECTION H.

ANCIENT METAL OBJECTS.

REPORT of the COMMITTEE appointed to report on the composition of ancient metal objects (Mr. H. J. E. Peake, Chairman ; Dr. C. H. Desch, F.R.S., Secretary ; Prof. V. G. Childe, Mr. O. Davies, Prof. H. J. Fleure, F.R.S., Mr. C. Hawkes, Mr. W. Lamb, Mr. M. E. L. Mallowan, Mr. H. Maryon, Dr. A. Raistrick, Dr. R. H. Rastall).

The following report has been received from the Secretary :

This Committee continues the work of the Sumerian Committee, of which eight reports have been issued. The inquiries have shown that there is a demand among archæologists for facilities for the accurate analysis of ancient metallic objects, and for their comparison with naturally occurring ores. The fact that only a few milligrammes of metal are now required for a full analysis makes it possible for curators to allow sufficient drillings to be taken from complete objects, so that analysis and form may be correlated, instead of confining the analysis to fragments. The work has been continued in the Metallurgy Department of the National Physical Laboratory, and the writer is indebted to Miss I. H. Hadfield and Dr. G. Barr for their skilled assistance. The methods of micro-analysis have been mainly employed, but recently a great saving in time and cost has been effected by making quantitative determinations by means of the spectrograph. The drillings, or on occasion the edge of an object, are used as one electrode in a spark gap. The spectrum is photographed, and the relative intensities of lines corresponding with

various elements are determined with the aid of a Hilger micro-photometer. The analyses are then returned in the first instance as follows :

X Principal constituent.
xxxx Element present in analytical quantity.
xxx Heavy trace of element.
xx Trace of element.
x Faint trace of element.

Standard alloys of known composition are being accumulated, and by using them it is possible to replace these approximate indications by actual figures, of an accuracy approaching that of chemical analysis. The plates are retained, so that as opportunity offers the figures can be filled in. The Secretary will shortly retire from the Laboratory, but it is hoped to make arrangements for continuing the work.

An extensive series of fragments from Troy has been received from Prof. Blegen. During the past year twenty-five specimens have been examined, nineteen having been reported on earlier. A large number remains, which will be examined spectrographically. Broadly speaking, the specimens from Troy I–IV are of copper, mostly with high arsenic, but including two bronzes, whilst from Troy VI and VII bronzes greatly preponderate, and the proportion of arsenic is less, indicating a different source for the copper. We still lack analyses of ores from many of the possible sources of copper. The analyses given in mining reports usually pay little attention to those impurities, such as nickel and arsenic, which are regarded as key elements.

A fine series of fifteen knives and spear-heads, in an uncorroded condition, was received from Cyprus from Mr. J. R. Stewart. The objects included only one bronze, which contained several per cent. of zinc, as did one of the specimens free from tin. Arsenic and silver were prominent impurities, and a fuller examination of the plates will be made.

Spectrographic analyses were also made of nine objects from Tell Duweir, received from the Wellcome-Marston Expedition. Three were of gold, one of electrum, three of copper, and two of bronze, with varying impurities.

Miss Caton Thompson submitted eleven objects from Hureidha, South Arabia. Six were of copper and three of bronze, with one each of iron and silver. All these plates are being examined further.

Filings from an axe-hammer from Hungary were sent by Mr. Peake, the spectrographic analysis suggesting that the object was of native copper.

Four small objects from Hampshire were also examined spectrographically, two being received from Mr. Peake and two from Mr. J. F. S. Stone. Mr. Peake also submitted two fragments of pottery with black glaze, one being Tell Halaf ware from Arpachiyah, and the other al'Ubaid ware from Nineveh. In both instances the black pigment proved to be magnetic oxide of iron.

The cost of the work is covered by charges made to the persons or institutions submitting objects for analysis, but there is no margin for the examination of objects of interest to the Committee. A gift of £5 from Prof. Newbery has been received for this purpose.

The full analyses of Luristan bronzes, mentioned in the fourth report, have now been published in Vol. I of Pope and Ackermann's *Survey of Persian Art* (Oxford University Press, 1939). W. Witter's *Die älteste Erzgewinnung im nordisch-germanischen Lebenskreis* has been completed by the publication of the second volume, and contains a very large number of analyses of European objects and of the ores of Central Europe.

BLOOD GROUPS

REPORT of the COMMITTEE appointed to investigate blood groups among primitive peoples (Prof. H. J. FLEURE, F.R.S., Chairman; Prof. R. RUGGLES GATES, F.R.S., Secretary; Dr. F. W. LAMB, Dr. G. M. MORANT).

A SMALL number of natives were tested in 1936 by Dr. F. W. Vint, Medical Research Laboratory, Nairobi, Kenya, with serum kindly supplied by Messrs. Parke, Davis & Co. As it has not been possible to continue this work, the results obtained are recorded here as follows :—

	O.	A.	B.	AB.		
Bantu . . .	29	20	20	4	=	73
½-Hamite . .	2	1	2	—	=	5
Nilote . . .	16	4	12	1	=	33
Mixed . . .	4	2	3	1	=	10
Totals . .	51	27	37	6	=	121
Per cent. . .	42·1	22·3	30·6	5·0		

The blood-grouping done during 1936 and 1937 in Assam may be summarised here. The tests were made on various tribes in the Naga Hills by Dr. E. Vieyra at Kohima and Dr. Kundu at Mokokchung, under the general supervision of Mr. J. P. Mills, the Honorary Director of Ethnography, with serum kindly supplied by the Haffkine Institute in Bombay.

The Angamis, Lhotas, Semas and Rengmas are known historically to be of similar stock. The numbers tested are given below.

	O.	A.	B.	A.B.		
Angamis . .	34	33	24	5	=	96
Per cent. . .	35·4	34·4	25·0	5·2		
Lhotas . . .	4	7	3	1	=	15
Semas . . .	15	7	3	0	=	25
Rengmas . .	3	0	1	0	=	4
Total . .	56	47	31	6	=	140
Per cent. . .	40	33·6	22·1	4·3		

It will be seen that the percentages for these four tribes together do not differ appreciably from those for the Angamis alone. Larger numbers of tests are required, to determine whether the Semas, Angamis and Lhotas show significant differences.

Three other tribes were tested as follows :

	O.	A.	B.	AB.		
Konyaks . .	58	51	13	5	=	127
Per cent. . .	45·7	40·2	10·2	3·9		
Aos . . .	27	13	13	4	=	57
Per cent. . .	47·4	22·8	22·8	7·0		
Thado Kuki . .	16	25	27	15	=	83
Per cent. . .	19·3	30·1	32·5	18·1		

Total tested in Assam . 407

These results are in accord with the view of Mr. J. P. Mills that the Konyaks are more primitive than the Angami-Rengma, that the Konyaks and Aos have much

in common, and that the Thado Kuki are an entirely different race. The Konyaks and Aos, being high in O and low in B, may be regarded as the most primitive in blood-grouping, the Thado Kuki being much higher in B and very low in O.

Two later series of tests made on the Angami and Thado Kuki between August 1937, and March 1938, with fresh lots of sera, gave results indicating that the B serum was for some reason more or less completely inactive. These results, numbering 171 tests, were therefore discarded. It is hoped to resume this work in the Naga Hills soon.

In the Andaman Islands five tests were obtained from the wild Jarawa tribe and five from the friendly Onges. The results, though so few, are of considerable interest and a note on the subject will be published elsewhere.

In Travancore, arrangements have been made through the Government officials, and tests are being taken of various tribes by Dr. C. O. Karunakaran, as serologist, with the aid of Mr. L. A. Krishna Iyer as ethnologist. 171 Kanikkars have been tested, and these are to be followed by Pulayas and other tribes. The results are markedly different from the general population in Trivandrum. Interesting differences in the titre of agglutination are also being found, some individuals giving a strong reaction with O serum who react very weakly with A or B serum. These and other phenomena are being studied by using sera in different dilutions.

Dr. Eileen Macfarlane has obtained a grant from the Royal Society towards her work in testing the Lepchas, Gonds and other tribes in India.

A paper has been published on the blood groups and other features of the Micmac Indians in Nova Scotia (*J. Anthrop. Inst.*, Vol. 68, pp. 283–98). These results are of interest for comparison with Indians from British Columbia and other parts of Canada, and also in relation to racial crossing. Anthropometric measurements and blood-group tests have been made by Mr. A. Ammar on over 1,000 Egyptians in Sharqiya Province, Northern Egypt.

Blood-group tests combined with anthropometric measurements have been carried out in parts of Co. Antrim, Northern Ireland, by Dr. John M. Mogey and Dr. G. L. Taylor. The ancestors of all individuals tested have resided in the district for at least three generations. These results should show whether local differences can arise in small isolated populations. Some 300 tests have already been made.

It has been suggested that infantile digestive disorders may in certain cases be due to a difference between the blood group of the mother and the nursing child. Dr. N. Kossovitch, of the Pasteur Institute in Paris, has obtained certain results which favour this view, and blood-group tests have been set in motion at St. George's Hospital, London, which should furnish further evidence on this question.

DERBYSHIRE CAVES

SEVENTEENTH INTERIM REPORT of the COMMITTEE appointed to co-operate with a Committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire District (Mr. M. C. Burkitt, Chairman; Mr. A. Leslie Armstrong, Secretary; Prof. H. J. Fleure, F.R.S., Prof. D. A. E. Garrod, Dr. J. Wilfred Jackson, Prof. L. S. Palmer, Mr. H. J. E. Peake).

Creswell Crags.—Mr. Leslie Armstrong, F.S.A., reports as follows:

'*The Yew Tree Shelter.*—A further extensive area at the western end of this rock shelter has been excavated, but the evidence of occupation obtained proved to be very scanty, consisting of a meagre scatter of flint flakes and artifacts on the late Aurignacian and the Azilio-Tardenoisian horizons.

'With the exception of one small hearth there was no evidence of actual occupation in this area and the artifacts appear to be a spread derived from the extensive living zone adjoining. This was somewhat surprising as that portion of the shelter is protected by a projecting rock wall at right angles to the main wall and, in general character, appears to offer a most desirable habitation site, which, in view of the occupation of the central and less protected area of the shelter, might be expected to yield abundant evidence ; but this anticipation was not realised.

'The excavations revealed a deposit 18 in. in thickness of recent humus, sand and small stones, overlying the Palæolithic horizon, obviously washed down from the plateau above during rain storms, through a fissure in the cliff.

'In Palæolithic times this torrent action was apparently more violent and more frequent and had carried down not only earth, but large stones and rocks also ; thereby rendering that portion of the shelter much less suitable for occupation than its present condition suggests. A further area of the central zone of the shelter has been systematically excavated and has added considerably to the evidence already obtained and yielded, in addition to artifacts of flint, a bone awl and fragments of Mammoth ivory, also bones of Woolly Rhinoceros and Bear.

'*Whitwell Cave.*—A small cave was located in the autumn of 1938, situated in a dry valley flanked by low limestone cliffs, north of Whitwell Church, in the vicinity of Creswell. Half of this cave has been excavated by Mr. Leslie Armstrong and Dr. Arthur Court, to a depth of 4 ft. The cave is devoid of stalagmite, but contains an undisturbed deposit of Pleistocene age covered by layers of later date which have yielded Iron Age pottery and flint artifacts of Neolithic and Bronze Age date. The Pleistocene horizon consists of closely compacted red cave-earth and has yielded a bone piercer and flint blades and scrapers of Upper Aurignacian facies. The faunal remains are scanty, but include Reindeer, Bear and Bison. The bed rock has not yet been reached. A sterile layer of frost riven slabs, at 3 ft. 6 in., appears to correspond with the upper slab layer in the Pin Hole Cave, but a definite correlation has not yet been established.

'*Whaley Rock Shelter No.* 2.—The Pleistocene horizon has been exposed over the whole area of the section under examination and is now in course of excavation. Evidence of Azilio-Tardenoisian occupation was obtained in the layer immediately above the Pleistocene deposit and is comparable in general facies with that of the corresponding horizon of Mother Grundy's Parlour, Creswell.

'The Pleistocene deposit has yielded artifacts of Upper Aurignacian type, consisting of blades and scrapers, in association with a fauna including Bison, Horse, Reindeer and Hyæna.

'In common with all the caves and rock-shelters of the Creswell region, this Whaley shelter records not permanent, but casual occupation by nomadic hunters in Palæolithic times.

'A further grant of £25 is earnestly requested by the Committee for the continuation of the work at Creswell and Whaley and further research in the Creswell region.'

EARLY MINING SITES IN WALES.

REPORT of COMMITTEE appointed to investigate early mining sites in Wales (Mr. H. J. E. Peake, Chairman ; Mr. O. Davies, Secretary ; Dr. C. H. Desch, F.R.S., Mr. E. Estyn Evans, Prof. H. J. Fleure, F.R.S., Prof. C. Daryll Forde, Sir Cyril Fox, Dr. Willoughby Gardner, Dr. F. J. North, Mr. V. E. Nash Williams).

The Committee report that the excavations begun last year at the Orme's Head copper mines were continued and nearly completed this spring. Last year's

results had been somewhat inconclusive. No indubitably ancient dumps could be located at the vein-outcrop, and the numerous stone hammers, though old Celtic in type, seemed to have been thrown out of the old workings in modern times. A small test at a site behind Gogarth Hotel had seemed more interesting, and this excavation was continued this year. The site lies on a steep slope, and small hearth-platforms were found. The site yielded mainly animal bones and shells; the latter, of species which grow on rocks, seemed to show that in antiquity the sea extended much farther round the south side of Great Orme's Head than it does to-day, and that the sandhills and marsh, on which the present 'West Shore' is built, are of recent formation. The presence of stone hammers similar to those from the tips indicates that the place was inhabited by a population of miners; topographical considerations suggest that it was the port for the mines, lying as it does at practically the only point where it is possible to descend from the summit without intervening precipices. The date of the site was established by Romano-British sherds and by two bone bodkins which can be paralleled on other sites of the same period. This accords with such evidence as we possess about the mine (*c.* 300 A.D.), and affords a valuable indication for the date of the hammer-rubbers which are common on many Welsh mining sites.

SECTION K

TRANSPLANT EXPERIMENTS.

REPORT of COMMITTEE on Transplant Experiments (Sir ARTHUR HILL, K.C.M.G., F.R.S., Chairman; Dr. W. B. TURRILL, Secretary; Prof. F. W. OLIVER, F.R.S., Prof. E. J. SALISBURY, C.B.E., F.R.S., Prof. A. G. TANSLEY, F.R.S.).

THE experiments have been continued at Potterne, Wiltshire, along the lines suggested by the Committee. A fifth biennial report has been published in the *Journal of Ecology*, XXVI, 359 (1938), and a summary of results for the first ten years of the experiments has also been published (*Journal of Ecology*, XXVI, 380 (1938)).

It is requested that the Committee be kept in being for another year and that a grant of five pounds be made towards the cost of the experiments.

REPORT OF THE COUNCIL

TO THE GENERAL COMMITTEE FOR THE YEAR 1938–39.

Obituary.

The Council have had to deplore the loss by death of the following office-bearers and supporters :—

Mr. A. F. T. Atchison
Prof. H. Balfour, F.R.S.
Mr. C. O. Bartrum
Dr. Margaret Benson
Prof. J. W. Bews
Dr. L. H. Dudley Buxton
Dr. J. E. R. Constable
Prof. W. Cramp
Sir Frank Dyson, F.R.S.
Sir Henry Fowler, K.B.E.
Dr. A. Harker, F.R.S.
Sir Frederick Hobday
Mr. A. M. Hocart
Sir Robert Mond, F.R.S.
Prof. A. W. Porter, F.R.S.
Lady Poulton
Mr. E. W. Fraser Smith
Prof. A. Smithells, C.M.G., F.R.S.

Representation.

Representatives of the Association have been appointed as follows :—

Australia and New Zealand Association for the Advancement of Science, Jubilee Meeting .	Prof. F. T. Brooks, F.R.S.
British Standards Institution, Committee on the Standardisation of Letter Symbols . .	Sir James Henderson.
Association française pour l'Avancement des Sciences, Liége, July, 1939 . . .	Prof. C. D. Ellis, F.R.S.
International Geological Congress, 1940 . .	Prof. P. G. H. Boswell, F.R.S., and Prof. W. W. Watts, F.R.S.

At the Jubilee Meeting of the Australian and New Zealand Association, Prof. Brooks presented the following address :—

The Council of the British Association for the Advancement of Science offer cordial congratulations to the President and Council of the Australian and New Zealand Association for the Advancement of Science on the occasion of the Jubilee of the Association.

The two Associations share the common object implicit in their titles, and many members of the British Association know by personal contact with scientific workers in Australia and New Zealand how successfully that object has been pursued in these Dominions.

It is the earnest hope of the Council that the labours of the Australian and New Zealand Association for the cause of Science may be prosperously continued, and that the friendly relations between the two Associations may be maintained and strengthened.

Resolutions and Recommendations.

Resolutions and recommendations, referred by the General Committee to the Council for consideration, and, if desirable, for action, were dealt with as follows. The resolutions will be found in the *Report* for 1938, p. lviii.

(*a*) A resolution from Section H (Anthropology) dealing with the safeguarding of native tribes in Australia was forwarded in substance to the appropriate authorities through Dr. Donald Thomson, whose kind advice and co-operation the Council have gratefully to acknowledge.

(*b*) On the receipt of a resolution from the Committee of Section H (Anthropology) dealing with the desirability of making anthropology a compulsory subject of study in the training of probationers appointed to proceed to India and Burma, the Council were informed that the views of the Section would not be overlooked if at any time a general revision of the probationary course be contemplated, and that in the meantime certain lectures on anthropology had been arranged for the benefit of probationers.

(*c*) The Council has had under consideration a resolution from the Organising Committee of Section D (Zoology) to the effect that in order to allow for the proper investigation of applications for research grants a date not later than July 1 should be fixed for the reception of applications, and that Recorders of Sections should be instructed to obtain all relevant information to lay before the Sectional Committee when applications are considered. The Council refer this proposal to the General Committee for consideration and reference, if they think fit, to the Committee of Recommendations.

(*d*) The Council received, from the Division for the Social and International Relations of Science meeting at Reading (as stated in the report of the Division annexed hereto), a resolution urging that it be made compulsory, in urban areas with a population of 20,000 or more, effectively to pasteurise all milk before sale to consumers. The Council thought it desirable before any action were taken upon this resolution, a factual report on existing knowledge of the whole question of pasteurisation and sterilisation of milk should be obtained, if possible, and steps are being taken to this end.

Finance.

The Council have received reports from the General Treasurer throughout the year. His account has been audited and is presented to the General Committee.

The Council made the following grants from the funds under their control :—

	£
From the Caird Fund.	
Seismological investigations	100
Mathematical tables	200
From the Bernard Hobson Fund.	
Critical geological sections	60
From the Leicester and Leicestershire Fund.	
Mr. J. V. Westwood	40
Organisation of research in Education	10
Gaps in the informative content of Education	15

It was reported to the Council that the Committee of the Division for the Social and International Relations of Science were collaborating with PEP (Political and Economic Planning) on an inquiry into research in Britain, necessitating the employment of a full-time inquirer. The Council authorised a grant from Association funds of £100, equivalent to three months' salary for this inquirer, in order that the start of the work should not be unduly delayed. It was anticipated that funds would be available from other sources after this period.

Corporation Membership.—The following have been admitted to corporation membership since the previous report of the Council (list corrected to August 9, 1939) :—

Educational Institute of Scotland
County Borough of Brighton, for Booth Museum, Dyke Road, Brighton
Messrs. W. H. Allen, Sons, & Co., Queen's Engineering Works, Bedford
Messrs. William Denny & Brothers, Dumbarton
Messrs. Vickers-Armstrong, Ltd.
Messrs. Drysdale & Co., Bon Accord Works, Glasgow
Messrs. Babcock & Wilcox Ltd.

The Council gratefully acknowledge the kind help of Mr. R. W. Allen, C.B.E., in making known the conditions of corporation membership to many of his engineering colleagues.

PRESIDENT (1940), GENERAL OFFICERS, GENERAL COMMITTEE, AND COUNCIL.

President (1940).—The Council's nomination to the Presidency of the Association for the year 1940 (Meeting at Newcastle-upon-Tyne) is Sir Richard Gregory, Bt., F.R.S.

The General Officers have been nominated by the Council as follows :—

General Treasurer, Prof. P. G. H. Boswell, F.R.S.

General Secretaries, Prof. F. T. Brooks, F.R.S., Prof. Allan Ferguson.

General Committee.—The following have been admitted as members of the General Committee :—

Dr. R. O. Buchanan
Mr. C. R. Bury
Capt. C. Diver
Prof. E. Hindle
Prof. H. G. Jackson
Prof. R. G. W. Norrish, F.R.S.
Prof. J. Read, F.R.S.
Dr. E. H. Rodd
Mr. F. Sandon
Prof. W. Shearer
Prof. E. A. Spaul
Dr. C. J. Stubblefield
Prof. S. Sugden, F.R.S.
Prof. C. M. Yonge.

Council.—The retiring Ordinary Members of the Council are Prof. F. Aveling, Prof. F. Balfour Browne, Dr. C. R. Fay, Prof. A. V. Hill, Sec. R.S., Dr. J. A. Venn.

The Council have nominated as new members Prof. J. H. Hutton, Sir Richard Livingstone, and Prof. H. S. Raper, F.R.S., leaving two vacancies to be filled by the General Committee without nomination by the Council.[1]

The full list of Ordinary Members nominated is as follows :—

R. W. Allen, C.B.E.
Dr. F. W. Aston, F.R.S.
Sir T. Hudson Beare
Rt. Hon. Viscount Bledisloe, P.C., G.C.M.G., G.B.E.
Dr. W. T. Calman, C.B., F.R.S.
Prof. F. Debenham, O.B.E.
Prof. W. G. Fearnsides, F.R.S.
Prof. H. J. Fleure, F.R.S.
Prof. F. E. Fritsch, F.R.S.
Sir Richard Gregory, Bt., F.R.S.[1]
Prof. T. G. Hill
Prof. J. H. Hutton
Sir Richard Livingstone
Prof. T. S. Moore
Prof. J. C. Philip, O.B.E., F.R.S.
Prof. H. S. Raper, F.R.S.
Prof. J. G. Smith
Lt.-Col. W. Campbell Smith
Prof. C. Spearman, F.R.S.
Dr. C. Tierney.
Prof. Sir Gilbert Walker, C.S.I., F.R.S.
R. S. Whipple
J. S. Wilson

[1] *The General Committee, having accepted the Council's nomination of Sir Richard Gregory, Bt., F.R.S., to the Presidency of the Association, were actually in a position to fill three vacancies among ordinary members of the Council, and did so by appointing Dr. A. P. M. Fleming, C.B.E., Sir John Graham Kerr, M.P., F.R.S., and Prof. H. O. Meredith.*

FUTURE MEETINGS, ETC.

The General Committee have already accepted invitations for the Association to meet in Newcastle-upon-Tyne in 1940 and Belfast in 1941 and in Birmingham in 1942. The General Committee should be made aware that invitations for subsequent years have been received from Brighton and Plymouth, in addition to Swansea, to which reference was made in the previous report of the Council.

The Council have pleasure in reporting the receipt of a resolution from the Executive Committee of the Indian Science Congress Association in the following terms :—

> The Executive Committee of the Indian Science Congress Association have received with sincere pleasure and gratification the resolution of the Council of the British Association stating that the visit of their Scientific Delegation to India has been a complete success and has enabled the Members of the Delegation to make or renew personal contacts with Indian Scientific Workers and leaders of thought. They share with the Council of the British Association the belief that much good would result from the visit. The Executive Committee very much appreciate the friendly feelings expressed by the Council of the British Association on behalf of the Delegation to the authorities and individuals who contributed towards the success of the Silver Jubilee Session and expressed in particular their appreciation of the reference to the Executive Committee of the Indian Science Congress Association. The Executive Committee convey to the Council of the British Association their warmest appreciation of the manner in which the British Association have responded to their invitation to join the Indian Science Congress Association in joint session to celebrate the Silver Jubilee Session.

The Council have learnt with interest that informal conversations have taken place with regard to the possibility that the Association may be invited to form small delegations to visit the West Indies and Southern Rhodesia.

MISCELLANEA.

Relations with the American and French Associations.—The Council received with satisfaction the acquiescence of the American Association for the Advancement of Science to the proposal, adopted by the General Committee at the Cambridge Meeting, ' that active members of the Council of the British Association, and the executive committees and sectional secretaries of the American Association, should automatically become honorary members ' of each others' Associations during their terms of office. The plan for the interchange of lecturers between the two Associations in alternate years was carried forward, with the result that the Council were fortunate in securing the acceptance of Dr. Isaiah Bowman, President of Johns Hopkins University, to deliver the first lecture of this series at the Dundee Meeting.

The Council have gladly adopted a proposal of L'Association Française pour l'Adancement des Sciences, whereby the President, Vice-president, Secretary, Vice-Secretary, Treasurer, and Secretary of the Council of L'Association Française should be honorary members of the British Association, and that the President, General Treasurer, General Secretaries, and Secretary of the British Association should be honorary members of L'Association Française.

'The Advancement of Science,' quarterly publication of Report.—The General Officers, after considering a number of printers' estimates and reporting to Council, were authorised to accept the estimate of Messrs. Spottiswoode, Ballantyne & Co. Ltd., who have printed the reports of the Association for upwards of sixty years. The Council resolved that, to non-members of the Association, the published price

of each quarterly part should be 5*s.*, or by subscription payable in advance, 15*s.* (four parts).

Corporate Seal of the Association.—When the Association was granted armorial bearings they were substituted for the device previously used on the corporate seal. The Council are advised that this substitution should be approved by formal resolution, and they recommend the General Committee accordingly.

DOWN HOUSE COMMITTEE.

REPORT TO THE COUNCIL FOR THE YEAR 1938–39.

The number of visitors to Down House during the year ending June 6, 1939, has been 7,362, compared with 7,185 in 1937–38.

Among gifts to the collection during the past year, the following should be mentioned. Dr. C. G. Darwin, F.R.S., allowed reproductions to be made of selected pages from the original Diary of the Voyage of the *Beagle*. These were presented by Prof. F. T. Brooks, F.R.S., were exhibited at the Cambridge Meeting of the Association last year, and are now hung in the New Study at Down House. Prof. Brooks also presented a collecting bottle used by Darwin during the voyage and still containing specimens. It may be mentioned incidentally that an endeavour to answer a question put recently by a visitor to the house, resulted in the discovery that there is uncertainty as to the present location of some of the scientific collections made by Darwin during the voyage and either sent or taken home by him : it is intended to attempt to form a list of these and of their whereabouts so far as they are preserved. Two oil-colour views of the house, dating about 1820, have been presented by Mr. A. Johnson, a descendant of the then occupier. The measures so far taken to collect biographies of Darwin and contemporary literature bearing upon his work—a step commended by the Council in their report last year—have resulted in the acquisition of a number of useful books and papers not previously in the library. Special reference is due to a series of ' Darwin critiques ' collected by T. H. Huxley and bound together ; these have been presented by Dr. Julian Huxley. Further endeavours are being made to add to the collection.

The new edition of the Catalogue, referred to in the previous Report of the Committee, is now on sale. Its cost, thanks to the use of the Replika process for a considerable part of it, was much less than that of the first edition, and its sales will in due course leave a margin of profit.

The precipitation for the year 1938 read from the standard rain gauge, was 25·93 in., compared with 39·12 in. in 1937. The average for the district is of the order of 29 in.

During the international crisis in September 1938 it was arranged that the old kitchen of the house, and adjacent rooms, should form a first-aid station for Downe and district. Certain necessary fitting was carried out (and remains in place), and the premises were used, then and afterwards, for first-aid classes. The old kitchen has also been used for certain Women's Institute classes.

The Committee are glad to know that the Council expressed to the Orpington Urban District Council their satisfaction at the acquisition of the High Elms estate for the Green Belt. As the home of the Lubbock family and in particular of Sir John Lubbock, afterwards Lord Avebury, Darwin's close friend for nearly forty years, High Elms has an intimate relationship with Down House ; while it will be

remembered also that Lubbock was President of the Association in its Jubilee Year, 1887.

One of the custodians of the house, H. Robinson, terminated his employment with the Association as from April 5, 1939, after rendering valuable service since 1929. Certain adjustments of duties among other members of the staff have been made, and it has been found unnecessary immediately to fill his place by making a further full-time appointment; nor should this become necessary so long as the present arrangements work smoothly.

The financial statement for the year is included as usual in the General Treasurer's Accounts. It will be remembered that the generous grant from the Pilgrim Trust, £150 per annum in recent years, was to be 'tapered' to £100 in the past financial year and to £50 in 1938–39, after which it ceases. The Committee ask to be associated with any expression of thanks which the Council may convey to the Trust.

DIVISION FOR THE SOCIAL AND INTERNATIONAL RELATIONS OF SCIENCE

REPORT FOR THE YEAR 1938–39

The Division was founded by resolution of the General Committee of the Association in August 1938, with four main functions:

(*a*) To arrange meetings at the time and place of the annual meetings of the Association and also elsewhere at other times.

(*b*) To co-ordinate work dealing with the social relations of science, both at home and abroad.

(*c*) To be prepared to act in a consultative capacity, and to supply information to organisations, individuals, and the public.

(*d*) To initiate and carry out inquiries and research, and to secure publication of the results thereof.

The organisation of the Division is in the charge of a Committee whose personnel is as follows:

Chairman: Sir Richard Gregory, Bt., F.R.S.

Vice-Chairmen: Sir Daniel Hall, K.C.B., F.R.S.; Sir Frederick Gowland Hopkins, O.M., F.R.S.; Sir John Russell, F.R.S., and the Rt. Hon. Lord Stamp, G.C.B., G.B.E.

Committee: Prof. F. C. Bartlett, F.R.S.; Prof. J. D. Bernal, F.R.S.; Prof. P. M. S. Blackett, F.R.S.; Mr. Ritchie Calder; Mr. A. M. Carr-Saunders; Prof. S. Chapman, F.R.S.; Dr. C. H. Desch, F.R.S.; Prof. A. C. G. Egerton, Sec.R.S.; Prof. H. J. Fleure, F.R.S.; Mr. E. W. Gilbert; Mr. N. F. Hall; Mr. R. F. Harrod; Prof. A. V. Hill, Sec.R.S.; Sir Clement Hindley, K.C.I.E.; Prof. L. Hogben, F.R.S.; Dr. L. E. C. Hughes; Dr. J. S. Huxley, F.R.S.; Mr. D. Caradog Jones; Prof. H. Levy; Dr. C. S. Myers, C.B.E., F.R.S.; Mr. Max Nicholson; Sir John Orr, F.R.S.; Prof. J. C. Philip, F.R.S.; Prof. J. G. Smith; Prof. Sir George Stapledon, C.B.E., F.R.S.; Prof. F. J. M. Stratton; Prof. F. E. Weiss, F.R.S.; Mr. H. G. Wells; Mr. J. S. Wilson; Dr. S. Zuckerman; and the President and General Officers of the British Association, *ex officio*.

The following are members of the Executive Sub-Committee : the Chairman of the Committee, the General Officers of the Association, together with Mr. Ritchie Calder, Mr. A. M. Carr-Saunders, Dr. J. S. Huxley, F.R.S., Prof. H. Levy, and Sir John Orr, F.R.S.

The establishment of the Division was widely welcomed in the press and elsewhere, and from the outset the Committee received numerous suggestions regarding topics which might receive consideration. It was found expedient to form several sub-committees with special terms of reference. The work of these committees is set out in some detail below, and the following is a general review of matters dealt with by the main Committee.

Relations with other Organisations.

A statement of the aims and objects of the Division, together with a request for information on any work in the field of social relations of science, was circulated to some 350 associations, institutions and learned societies in the British Isles and abroad. From some of these bodies replies were received which indicated that much work has been done, or is in progress. Some of this work is as yet not widely known, and in certain instances opportunity has already been found for the Division to exercise its function of co-ordination. Many offers of co-operation were received from bodies particularly interested in the social impacts of science, and several valuable contacts have been made. Notably, the Division learned that PEP (Political and Economic Planning) proposed to prepare a report on the organisation of research in Great Britain, but was hampered by lack of funds to start the work. The Council of the Association, at the instance of the Divisional Committee, voted £100 as salary for the research worker appointed by PEP to collect the factual material. This enabled the work to proceed immediately, pending the acquisition of funds to maintain the inquiry from other sources. The necessary support has since been obtained from the Leverhulme Trustees, who have made available sufficient funds to carry on the inquiry until the autumn of 1940. The Division is represented on the committee supervising the work and will be associated with the report to be published in due course. Meanwhile an interim account of the work will be given at the Dundee Meeting of the Association.

Relations with Sections of the Association.

Some of the topics which came to the Division for attention were considered to be germane to the interests of various Sections of the Association and were referred to the appropriate Organising Sectional Committees. In this connection, papers and discussions have been arranged for the Dundee Meeting as follows : Section B (Chemistry), discussion on supply and utilisation of light metals ; Section F (Economics), papers on Scottish industries ; Section L (Education), discussions on education for industry and in industry. It has also been recommended to Sections B (Chemistry), C (Geology), F (Economics), and G (Engineering) that, with the assistance of the Division, a report should be prepared on the supply and utilisation of light metals.

Subjects for Consideration.

The wide variety of topics with which the Division has been concerned may be further judged from the following selection of suggestions which have received attention :

(*a*) Analysis of prospective effects of changes in population structure. This matter, which, as the Divisional Committee learned, is under investigation by the

Population Investigation Committee and the Population Policies Committee, will be dealt with in a discussion at the Dundee Meeting.

(*b*) Review of areas and objects worthy of protection on scientific grounds. This was referred in the first instance to the recently appointed National Atlas Committee of the Association (Section E, Geography), which, among the series of maps proposed to be prepared, is understood to contemplate one showing protected areas and sites.

(*c*) Incidence of taxation on scientific research. On this subject the Association of Scientific Workers have prepared memoranda. The Division recommended that the Association's representative on the Parliamentary Science Committee be requested to support any proposals which might be brought before that body by the A.S.W. with a view to introducing legislation intended to ameliorate hardships suffered by scientific research in the matter of taxation.

(*d*) Recommendations concerning details demanded in census returns and their analysis, which were referred to the Council of the Association.

(*e*) Broadcasts on scientific subjects. Liaison has been established with appropriate departments of the B.B.C.

(*f*) Scientific news in the Press. A Sub-Committee has been appointed to consider and report upon possible methods of improving and extending relations with the Press.

(*g*) Scientific exhibitions. In this connection it is under consideration whether an exhibition may be arranged during a meeting (or more than one meeting) of the Association in the near future.

(*h*) Co-operation with the International Council of Scientific Unions in relation to questionnaires on science and society issued by the Committee of the International Council dealing with Science and Social Relations.

(*i*) Assisting the Society for the Protection of Science and Learning. The Division directed to the American Association for the Advancement of Science an appeal for the stimulation of interest in the work of the above Society in relation to their work on behalf of intellectual refugees.

Representation.

Representatives were appointed as follows :

Prof. Allan Ferguson to the scientific committee of the National Book Council.

Prof. J. C. Drummond to the London meeting of the British Medical Association on Nutrition.

Sub-Committees.

(i) *Meetings.*—This Sub-Committee has made arrangements for public meetings of the Division of which details are given below.

(ii) *National Research Organisation.*—This Sub-Committee was appointed to consider and report on the desirability of supplementing existing national research organisations whether in normal circumstances or in times of emergency. With a view to ascertaining details concerning systems of controlling and distributing grants in aid of research in other countries an inquiry was directed to correspondents in U.S.A., France, Belgium, Holland, Denmark and the Dominions. Several replies have been received and a report will be prepared.

Two memoranda were prepared for the consideration of the Committee, by Prof. A. C. G. Egerton, Sec.R.S., and by Prof. J. D. Bernal, F.R.S., and Dr. Julian Huxley, F.R.S., respectively, dealing with expenditure of public funds on research and discussing the question of a Research Co-ordination Council. These were combined into one memorandum, and are under the consideration of the Divisional Committee. The Committee is in touch with PEP in respect of the report on

research in Great Britain, noted above, and is represented on the supervisory committee.

The Committee received notice of a proposal to establish a Committee of Science in the House of Lords and undertook to make contact with this Committee if and when established.

(iii) *Nutrition and Agriculture.*—This Sub-Committee was formed to assist in the co-ordination and presentation of work already done in nutrition and agriculture. The Sub-Committee decided that milk in its nutritional and allied aspects was a desirable topic for immediate attention, and it was arranged to hold a public meeting at Reading at which prominent authorities on the subject should be invited to read papers to be followed by discussion. A report on this meeting and on a resolution put forward from it to the Council is given below.

(iv) *Economic requirements of Nations.*—A Sub-Committee was appointed to consider means for the study of the economic requirements of nations in relation to the sources of raw materials, incidence of population, standards of living, industrial developments, etc.

(v) *Science and Industry.*—A Sub-Committee appointed to report on means of carrying forward an enquiry into the influence of scientific and technical developments on the relative importance of different industries, and on the total volume of employment, decided in the first instance that its work could, at this stage, be most effectively achieved by securing publicity for results already obtained and by co-ordinating researches in this field. The work of the Committee will be maintained along these lines. Several suggestions were made as to topics for discussion at meetings of the Division, e.g. the parallel study of the effects of science on an old industry (cotton) and a new industry (plastics) for which see the report of the Manchester Meeting below. The Committee has under consideration the establishment of a research worker, if necessity arises and funds are available, at the Oxford Institute or elsewhere.

(vi) *Social Psychology.*—On the recommendation of various Sections of the Association, the Division appointed a Sub-Committee to implement recommendations made in 1936 by the Social Psychology Committee of Section J (Psychology). The functions of this Committee, which are mainly of a co-ordinating character, include ' to make and maintain contact with the various bodies or individuals carrying on investigations in the different fields covered by social psychology, and, on the other hand, to take such steps as may be possible to stimulate and encourage investigation.'

(vii) *Finance.*—It is evident that the activities of the Division must involve expenditure. An addition has been made to the clerical staff of the Association on account, partly, of the additional office work resulting from the creation of the Division: a substantial increase in correspondence and circularising has been caused, as also additional printing. The meetings held by the Division in Reading, London and Manchester have each necessitated some expenditure on incidental expenses; and it may be noted in this connection that admission to these meetings has been free. The expenditure on account of the Division shown in the General Treasurer's account for the financial year ending March 31, 1939, was £46 16*s.* 6*d.*, in addition to the grant of £100 made for the inquiry on research in Great Britain as reported above. If it were possible to command larger funds, it cannot be doubted that the position of the Division would be materially stronger, especially in the direction of initiating or supporting inquiries such as, in several directions, have been already mentioned to the Committee. A Finance Sub-Committee made a recommendation to the Council that consideration should be given to the disirability of an appeal for funds to (*a*) private individuals and firms, (*b*) trusts at home, (*c*) trusts abroad, (*d*) H.M. Government. The Council adopted this recommendation, with the provision that of these possible sources, the first named should be first explored.

MEETINGS.

An important function of the Division has proved to be the arrangement of meetings for the discussion, not only at the time of the annual meeting of the Association but also elsewhere, of topics proposed to the Committee and considered to be appropriate to the Division. The following meetings have been held :

(1) *Reading*.—A meeting was held in the University of Reading, by permission of the Council of the University, on March 28, 1939, when the topic for discussion was Milk in its nutritional and allied aspects. Two sessions were held as follows :

First Session.—Sir Richard Gregory, Bt., F.R.S., in the chair.
Deficiences in present-day diet, by Dr. Harriette Chick, C.B.E.
Health aspects, by Prof. J. C. Drummond.
Implications of compulsory pasteurisation, by Dr. A. W. Scott.

Second Session.—Sir Daniel Hall, K.C.B., F.R.S., in the chair.
Agricultural aspects of production, by Mr. J. Mackintosh, O.B.E.
Distribution of cost : economic and social implications, by Mr. John Cripps.

The meeting, which was preceded by a visit to the National Institute for Research in Dairying, at Shinfield, was attended by some two hundred people, including representatives appointed by the Milk Marketing Board, Ministry of Agriculture, Co-operative Societies, Dairy firms, Farmers' Unions, Associations of Medical Officers of Health, and other organisations. The papers were followed by discussion, and the following resolution was recommended to be sent to the Council of the Association for consideration and possible action :

' In view of the proved danger of the spread of epidemic and other diseases by the consumption of raw milk, of the efficiency of controlled pasteurisation in abolishing this danger and of the slight damage to the nutritive and other properties of milk caused by effective pasteurisation, it is essential for the national health that it be made compulsory in all urban areas with a population of over 20,000 or more to pasteurise effectively all milk before sale to consumers to ensure its safety and to assist in securing that increase in the *per capita* consumption of liquid milk which is essential for improvement in the national level of nutrition."

The Council, after consideration and consultation with the Nutrition Sub-Committee, considered it desirable that before taking any action on this resolution, a factual report on the whole question of the pasteurisation and sterilisation of milk should be procured, and steps are being taken to do this.

(2) *London*.—A meeting was held in the Royal Institution, by permission of the Managers, on May 25, 1939, Sir Richard Gregory, Bt., F.R.S., in the chair, when the following papers were read before an audience of some two hundred and fifty :

Developments in the impact of science on society, by Prof. Ernest Baker.
How the application of science to agriculture is impeded, by Sir Daniel Hall, K.C.B., F.R.S.

Prof. Barker's paper was an objective study of the social implications of science, and Sir Daniel Hall spoke on the various ways in which British agriculture is frustrated by time-lag in the application of scientific knowledge.

(3) *Manchester*.—In co-operation with the Manchester Literary and Philosophical Society, a meeting of the Division was held in the Physics Department of Manchester University, by permission of the Vice-Chancellor, on June 21, 1939. The meeting was preceded by an informal conversazione in the house of the Manchester Literary and Philosophical Society, during the evening of June 20. The programme of the meeting was as follows :

First Session.—11.0 A.M. to 12.30 P.M.

Chairman : Prof. J. S. B. Stopford, F.R.S., Vice-Chancellor of the University.

Speakers : Sir Richard Gregory, Bt., F.R.S., Chairman of the Division, on The Aims of the Division.

Prof. H. Levy on Social Relations of Science : Principles and Methods of Analysis (being the Alexander Pedler Memorial Lecture).

Second Session.—2.15 to 3.45 P.M.

Chairman : Prof. D. R. Hartree, F.R.S., President of the Manchester Literary and Philosophical Society.

Speaker : Dr. F. C. Toy on The Influence of Science on the Cotton Industry.

Third Session.—4.15 to 6.0 P.M.

Chairman : Sir Richard Gregory, Bt., F.R.S.

Speakers : Dr. V. E. Yarsley and Mr. E. G. Couzens on The Plastics Industry.

It is hoped to publish reports of all the above meetings in due course in the forthcoming quarterly publication of the Association, *The Advancement of Science.* The Manchester Literary and Philosophical Society is publishing Prof. Levy's Alexander Pedler Lecture and the papers on the cotton and plastics industries.

(4) *Dundee.*—Arrangements have been made for three sessions of the Division during the Annual Meeting of the Association, when the subjects for discussion will include Research in Great Britain (an interim report on the PEP inquiry being presented) ; Population Problems ; International Intellectual Co-operation ; and Nutrition ; and Sir Richard Gregory, Bt., F.R.S., will deliver a lecture on Science and Social Ethics. Full particulars will be furnished in the programme of the Dundee Meeting.

General Conclusions.

In conclusion, it may be said that the Division has already in view wide fields of activity in each of the main functions assigned to it, and stated at the opening of this, its first annual report. Those who have been most closely concerned with its work have acquired the impression that important schemes for strengthening the social and international relations of science, much valuable investigation into relevant problems, are at the present time the concern of many—perhaps too many—organisations. The work of co-ordination, as will be apparent, has already been entered upon in certain directions : with the co-operation of other bodies seeking the same object it should be capable of great extension. In this, as in the function of consultation, the Division will welcome approaches by any kindred organisation. In the field of inquiry and research the possibilities within the scope of the Division will be limited only by the financial resources which the Association is, or may become, able to command.

GENERAL TREASURER'S REPORT, 1938–39.

THE General Treasurer's Annual Account is doubtless studied carefully by all Members who have the Association's interests at heart : it is nevertheless desirable that attention should be directed from time to time to our general financial policy. In view of the recent establishment of the Division for the Social and International Relations of Science and the decision to publish quarterly instead of annual reports, the present occasion would seem to be particularly appropriate for such a review.

In the management of the British Association the preparation of an estimate of income and expenditure is rendered peculiarly difficult by the wide fluctuation of certain items, notably the revenue from membership subscriptions, from year to year. Yet it is necessary that revenue should be stabilised as firmly as possible if we are to know the extent to which research committees and new activities can be financed.

In the past the excess of income over expenditure was wholly applied as grants in aid of research. As the annual membership fluctuated so widely, these grants necessarily varied considerably in number and amount. In the present accounts they are set out in a separate schedule. Efforts directed to stabilising the position therefore necessitated the ordering of the accounts in such a manner that non-recurrent items of income and expenditure were not allowed to interfere with the amount available for research. The obvious way to achieve this aim lay in the institution of a compensating fund. A fund of this nature has been built up during the past five years to a total of £2,000, and appeared in last year's accounts as Contingency Fund A ; its name has been changed to Grants Equalisation Fund. The accumulation of a second such fund (which appeared in last year's accounts as Contingency Fund B, here simply Contingency Fund) has now proved possible. Thanks to the large membership of the Cambridge Meeting, this fund has been augmented in the present year by the sum of £352 15*s.* 2*d.* It now stands at £382 11*s.* 5*d.* and will form a nucleus for exceptional expenditure such as that required for overseas delegations, special exchange lecturers and the like. But we can hardly expect, although we may hope, that the average attendance at the next few Annual Meetings will equal that at Cambridge. In view of the additional costs that must be met in the matters of printing and Divisional activities, the growth of the fund will necessarily be slow.

Expenditure directly attributable to the work of the new Division will be seen from the accounts to amount to £170. Further, there is additional printing, postage, stationery, and office assistance, the cost of which is difficult to allocate. As the activities of the Division increase, it will clearly be impossible to finance them unless our income is augmented by donations and additional membership.

Efforts are being made to induce those who intermit their subscriptions and attendance at the Annual Meeting to become regularly subscribing members ; also to increase the list of Life Members and Corporation Members. I have recently issued an appeal dealing with the need for extension of membership, in which new activities of the Association, including those mentioned above, are detailed. Co-operation in these efforts will be warmly welcomed from all those who appreciate the benefits that Science confers and wish to aid the Association in discharging its function of the advancement of science.

P. G. H. BOSWELL,
General Treasurer.

Balance Sheet,

Corresponding Figures 31st March, 1938. £ s. d.	LIABILITIES		£ s. d.	£ s. d.
	GENERAL PURPOSES :—			
	Sundry Creditors			748 16 11
	Hon. Sir Charles Parsons' gift (£10,000) and legacy (£2,000) .			12,000 0 0
	The late Sir Alfred Ewing's legacy			500 0 0
	British Science Guild : Capital Fund			3,431 9 1
	Accumulated Fund (including Bequest of £10 from Jaakoff Prelooker)			
	As per last Account		16,281 13 6	
	Less Transfer to Overseas Delegations Fund .		783 4 6	
				15,498 9 0
	Yarrow Fund			
	As per last Account		4,361 6 5	
	Less Transferred to Income and Expenditure Account under terms of the gift . .		396 18 2	
				3,964 8 3
	Life and Corporate Compositions			
	As per last Account		3,258 19 2	
	Add Received during year :—			
	Life Compositions . .	215 10 0		
	Corporate Compositions .	52 10 0		
			268 0 0	
			3,526 19 2	
	Less Transferred to Income and Expenditure Account		30 0 0	
				3,496 19 2
	Grants Equalisation Fund			2,000 0 0
	Contingency Fund			
	As per last Account		29 16 3	
	Amount transferred from Income and Expenditure Account		352 15 2	
				382 11 5
	Overseas Delegations Fund			
	Transfer from Accumulated Fund . . .		783 4 6	
	Less Expended during year		2 0 7	
				781 3 11
42,648 7 2				42,803 17 9
	SPECIAL PURPOSES :—			
	Caird Fund			
	Balance at 1st April, 1938		9,750 14 2	
	Add Excess of Income over Expenditure for the year		100 3 1	
9,750 14 2				9,850 17 3
	Mathematical Tables Fund			
	Balance at 1st April, 1938		23 8 7	
	Receipts from Sales		25 13 6	
23 8 7				49 2 1
	Cunningham Bequest Fund			
	Balance at 1st April, 1938		1,407 18 6	
	Add Excess of Income over Expenditure for the year		34 7 5	
1,407 18 6				1,442 5 11
	Carried forward			54,146 3 0

31st March, 1939

Corresponding Figures 31st March, 1938. £ s. d.	ASSETS	£ s. d.	£ s. d.
	General Purposes :—		
	Investments as scheduled with Income and Expenditure Account, No. 1	42,582 9 5	
	Sundry debtors and payments in advance . .	53 2 11	
	Cash at bank	139 10 7	
	Cash in hand	28 14 10	
42,648 7 2			42,803 17 9
	Special Purposes :—		
	Caird Fund Account		
	Investments (see Income and Expenditure Account, No. 2)	9,582 16 3	
	Cash at bank	268 1 0	
9,750 14 2			9,850 17 3
	Mathematical Tables Fund Account		
23 8 7	Cash at bank		49 2 1
	Cunningham Bequest Fund Account		
	Investments (see Income and Expenditure Account, No. 3)	1,305 7 2	
	Cash at bank	136 18 9	
1,407 18 6			1,442 5 11
	Carried forward . . .		54,146 3 0

Balance Sheet,

LIABILITIES (*continued*)

Corresponding Figures 31st March, 1938. £ s. d.			£ s. d.	£ s. d.
	Brought forward			54,146 3 0
	Toronto University Presentation Fund			
	Capital		178 11 4	
	Revenue		4 7 6	
182 18 10				182 18 10
	Bernard Hobson Fund			
	Capital		1,000 0 0	
	Revenue—Balance per last Account . .		31 7 9	
	Add Excess of Income over Expenditure for the year		43 6 6	
1,031 7 9				1,074 14 3
	Leicester and Leicestershire Fund, 1933			
	Capital		1,000 0 0	
	Revenue—Balance per last Account . . .	41 6 8		
	Less Excess of Expenditure over Income for the year	31 16 1		
			9 10 7	
1,041 6 8				1,009 10 7
	Herbert Spencer Bequest Fund		723 4 6	
	Less Excess of Expenditure over Income for the year		90 13 10	
723 4 6				632 10 8
	Norwich Fund, 1935			
	Balance per last Account		54 2 0	
	Less Expenditure for year		54 2 0	
54 2 0				– – –
	Radford Mather Lecture Fund			
	Capital		250 0 0	
	Add Excess of Income over Expenditure for the year		7 5 6	
289 4 6				257 5 6
	Down House			
	Endowment Fund		20,000 0 0	
	Sundry Creditors and Credit Balances .		29 15 4	
	Cash balance overdrawn		99 15 1	
20,013 5 1				20,129 10 5
77,195 17 9				£77,432 13 3

NOTE.– There are contingent Liabilities in respect of grants voted to Research Committees at Cambridge and by Council in 1938 but not claimed at 31st March, 1939, as follows :

	£ s. d.
General Fund	212 4 8
Caird Fund	139 10 1
Hobson Fund	60 0 0
Leicester and Leicestershire Fund	23 19 9
	435 14 6

I have examined the foregoing Account with the Books and Vouchers and certify the Investments, and the Bank have certified to me that they hold the Deeds

Approved :
EZER GRIFFITHS
R. S. WHIPPLE } *Auditors.*

31st March, 1939 (*continued*)

Corresponding Figures 31st March, 1938. £ s. d.	ASSETS (*continued*)		£ s. d.	£ s. d.
	Brought forward			54,146 3 0
	Toronto University Presentation Fund Account			
	Investments (see Income and Expenditure Account, No. 4)		178 11 4	
	Cash at bank		4 7 6	
182 18 10				182 18 10
	Bernard Hobson Fund Account			
	Investments (see Income and Expenditure Account, No. 5)		1,000 0 0	
	Cash at bank		74 14 3	
1,031 7 9				1,074 14 3
	Leicester and Leicestershire Fund, 1933 *Account*			
	Investments (see Income and Expenditure Account, No. 6)		1,000 0 0	
	Cash at bank		9 10 7	
1,041 6 8				1,009 10 7
	Herbert Spencer Bequest Fund Account			
	Investments (see Income and Expenditure Account, No. 8)		608 16 0	
	Cash at bank		23 14 8	
723 4 6				632 10 8
	Norwich Fund, 1935 *Account*			
51 2 0	Cash at bank			– – –
	Radford Mather Lecture Fund Account			
	Investments (see Income and Expenditure Account, No. 9)		250 0 0	
	Cash at bank		7 5 6	
289 1 0				257 5 6
	Down House Account			
	Endowment Fund Investments (see Income and Expenditure Account, No. 7) . . .		20,000 0 0	
	Cash in hand		22 7 11	
	Sundry debtors and payments in advance .		67 4 6	
	Suspense Account			
	Excess of Expenditure over Income for the year .	70 10 7		
	Less Credit balance as per last account . .	30 12 7		
			39 18 0	
20,043 5 1				20,129 10 5
77,195 17 9				£77,432 13 3

the same to be correct. I have also verified the Balance at the Bankers and of Down House.

W. B. Keen, *Chartered Accountant.*
23 Queen Victoria St., London, E.C. 4.
29th June, 1939.

INCOME AND EXPENDITURE ACCOUNTS FOR THE YEAR ENDED 31ST MARCH, 1939

No. 1. General Income and Expenditure

Corresponding Figures 31st March, 1938. £ s. d.	*Investments :*				£	s.	d.	
		£6,749	12s. 2d.	Consolidated 2½ per cent. Stock, at cost	5,142	3	3	
		£3,600	0s. 0d.	India 3 per cent. Stock, at cost	3,522	2	6	
		£879	14s. 9d.	Great Indian Peninsula Railway 'B' Annuity £43, at cost	827	15	0	
		£52	12s. 7d.	War Stock (Post Office Issue), at cost	54	5	2	
		£1,400	0s. 0d.	3½ per cent. War Loan Bonds, at cost	1,393	16	11	
		£7,652	10s. 5d.	3½ per cent. War Loan Inscribed Stock, at cost	7,714	14	8	
		£12,994	16s. 6d.	4½ per cent. Conversion Stock, at cost	12,844	8	4	
		£6,368	15s. 7d.	3½ per cent. Conversion Stock, at cost	5,304	8	11	
		£94	7s. 0d.	4½ per cent. Conversion Stock (Post Office Issue), at cost	62	15	0	
		£4,184	18s. 2d.	3 per cent. Local Loans, at cost	3,073	12	2	
		£1,000	0s. 0d.	4 per cent. Funding Loan Bonds	1,170	0	0	
		£100	0s. 0d.	5 per cent. Great Western Railway Consolidated Pref. Stock	125	0	0	
		£345	16s. 8d.	3 per cent. London County Consolidated Stock	347	7	6	
		£981	10s. 0d.	4 per cent. Commonwealth of Australia Stock	1,000	0	0	
41,979 7 7	*(Value of Stocks at 31/3/38, £44,244 4s. 9d.)*				£42,582	9	5	(Value of Stocks at 31/3/39, £42,358 3s. 1d.)

Cash at bank and in hand, £168 5s. 5d.

Corresponding Figures 31st March, 1938. £ s. d.	EXPENDITURE	£	s.	d.	Corresponding Figures 31st March, 1938. £ s. d.	INCOME		£	s.	d.
40 9 0	To Heat, Lighting and Power	34	15	8	74 0 0	By Old Annual Regular Members		68	0	0
87 18 10	„ Stationery	99	14	6	1,211 4 6	„ Annual Members for Meeting only		2,084	6	0
1 0 0	„ Rent	1	0	0	532 12 6	„ Annual Members, with Report		627	15	3
143 17 10	„ Postages	218	17	9	116 15 0	„ Transferable Tickets		72	18	0
119 1 11	„ Travelling Expenses	171	4	1	91 5 0	„ Student Members		106	10	0
56 16 10	„ Exhibitioners	67	7	6		„ Life Compositions : amount transferred				
84 0 0	„ Audit and Accountancy	84	0	0	55 10 0	on expiry of membership		30	0	0
	„ Subscription to Parliamentary Science					„ Sale of Publications	£489 19 3			
10 10 0	Committee	10	10	0		*Less* Transferred to				
292 17 0	„ General Expenses	265	2	10		Mathematical Tables				
1,967 14 0	„ Salaries and Wages	2,089	7	0		Fund	25 13 6			
143 2 0	„ Pension Contributions	143	7	0	426 11 6			464	5	9

1937–8	Expenditure		£ s. d.
1,032 8 6	To Printing, binding, etc.		1,509 5 8
26 12 10	,, Norman Lockyer Lecture Expenses		38 12 9
12 1 0	,, Alexander Pedler Lecture Expenses		23 11 6
– – –	,, Radford Mather Lecture: Expenses of 1937 Lecture		39 4 6
	,, Division for Social and International Relations of Science: Expenditure incurred during year:		
	Payment to PEP (Political and Economic Planning), in aid of Survey of Research	£100 0 0	
	Printing, Postages and Stationery	38 5 8	
	Reference books	3 8 8	
	Reading Meeting: travelling expenses, etc.	5 2 2	
			146 16 6
– – –	,, Notes and Queries on Anthropology (6th Edition)		4 0 0
463 6 2	,, Grants paid to Research Committees (see Schedule)		498 0 3
88 19 2	,, Balance, being excess of Income over Expenditure for the year, carried to Contingency Fund		352 15 2
290 10 6	*1937-8 Non-recurring items*		– – –
4,861 5 7			£5,797 12 8
184 5 9	Grants to research authorised but not yet claimed at 31st March, 1939, amount to		£212 4 8

1937–8	Income	£ s. d.
252 13 2	By Advertisements in B.A. publications	226 7 4
1 16 0	,, Unexpended balance of grant returned	2 11 3
18 0 0	,, Liverpool Exhibitioners	18 0 0
21 16 0	,, Income Tax recovered	29 1 1
1,603 8 11	,, Interest on investments	1,615 12 7
– – –	,, Interest on current account	8 9
2 0 6	,, Donations	11 0
32 3 4	,, Proceeds of Sale of Badges at Cambridge	54 7 6
383 9 8	,, Sir Alfred Yarrow's Gift: amount transferred	396 18 2
37 19 6	,, *Grant from Herbert Spencer Bequest towards cost of Office decoration*	– – –
4,890 7 11		£5,797 12 8

No. 2. Caird Fund

The unconditional gift of Sir James Caird, in 1912, administered by the Council in accordance with recommendations adopted by the General Committee in 1913.

Corresponding Figures 31st March, 1938. £ s. d.	Investments:		£ s. d.	
	£2,627 0s. 10d.	India 3½ per cent. Stock, at cost	2,400 13 3	
	£2,100 0s. 0d.	London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock, at cost	2,190 4 3	
	£2,500 0s. 0d.	Canada 3½ per cent. Registered Stock, 1930/50, at cost	2,397 1 6	
	£2,000 0s. 0d.	Southern Railway Consolidated 5 per cent. Preference Stock, at cost	2,594 17 3	(Value at 31/3/39, £7,476 8s. 1d.)
			£9,582 16 3	
9,582 16 3	(*Value at 31/3/38, £8,772 9s. 5d.*)		Cash at bank, £268 1s. 0d.	

Corresponding Figures 31st March, 1938. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1938. £ s. d.	INCOME	£ s. d.
401 2 6	To Grants paid (see Schedule)	256 9 11	295 11 2	By Dividends and Interest	288 15 6
– – –	,, Balance, being excess of Income over Expenditure for the year	100 3 1	64 9 8	,, Income Tax recovered	67 17 6
			41 1 8	,, *Balance, being excess of Expenditure over Income for the year*	– – –
401 2 6		£356 13 0	401 2 6		£356 13 0

Grants to research authorised, but not yet claimed at 31st March, 1939, amount to £139 10 1

No. 3. Cunningham Bequest

A legacy received by the Association in 1929 in trust under the will of Lt.-Col. A. J. C. Cunningham, for the preparation of new mathematical tables in the theory of numbers ; administered by the Council.

Corresponding Figures 31st March, 1938. £ s. d.	Investments :	£ s. d.	
	£1,187 6s. 10d. Consolidated 2½ per cent. Stock	653 0 9	
	£300 0s. 0d. Port of London 3½ per cent. Stock, 1949/99	216 0 0	
	£862 13s. 3d. Local Loans 3 per cent. Stock, at cost	436 6 5	(Value at 31/3/39, £1,564 15s. 5d.)
1,305 7 2	*(Value at 31/3/38, £1,918 18s. 1d.)*	£1,305 7 2	

Cash at bank, £136 18s. 9d.

Corresponding Figures 31st March, 1938. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1938. £ s. d.	INCOME	£ s. d.
63 10 0	To Grants for the preparation of tables	31 10 0	63 10 2	By Interest	63 6 3
12 8 8	,, Balance, being excess of Income over Expenditure for the year	34 7 5	2 8 6	,, Income Tax recovered	2 11 2
65 18 8		£65 17 5	65 18 8		£65 17 5

No. 4. Toronto University Presentation Fund

A fund voluntarily subscribed by members present at the Toronto Meeting in 1924. From the income a presentation of two bronze medals each year is made, together with presents of books, to selected students in pure and applied science respectively.

Corresponding Figures 31st March, 1938. £ s. d.	Investment :		
178 11 4	£175 3½ per cent. War Stock at cost	£178 11 4	(Value at 31/3/39, £166 13s. 9d.)
	(Value at 31/3/38, £177 12s. 6d.)		

Cash at bank, £4 7s. 6d.

Corresponding Figures 31st March, 1938. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1938. £ s. d.	INCOME	£ s. d.
6 2 6	To awards	£6 2 6	6 2 6	By Interest	£6 2 6

No. 5. Bernard Hobson Fund

The bequest of Mr. Bernard Hobson, 1933 ; the income to be applied to the promotion of geological research ; administered by the Council.

Corresponding Figures 31st March, 1938. £ s. d.	*Investments :*	£ s. d.	
	£450 0s. 0d. 4 per cent. Victory (Bearer) Bonds at cost . . .	491 13 6	
	£601 9s. 0d. 3 per cent. Local Loans at cost	508 6 6	(Value at 31/3/39,
1,000 0 0	*(Value at 31/3/38, £1,011 17s. 7d.)*	£1,000 0 0	£955 13s. 1d.)

Cash at bank, £74 14s. 3d.

Corresponding Figures 31st March, 1938. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1938. £ s. d.	INCOME	£ s. d.
62 10 0	*To Grants paid to Committee* . . .	– – –	31 11 0	By Interest	31 2 0
– – –	,, Balance, being excess of Income over Expenditure for the year . .	43 6 6	4 5 6	,, Income Tax recovered . . .	4 10 0
				,, Unexpended balance of grant refunded	7 14 6
			26 13 6	,, *Balance, being excess of Expenditure over Income for the year*	– – –
62 10 0		£43 6 6	62 10 0		£43 6 6

Grants to research authorised but not yet claimed at 31st March, 1939, amount to £60 0 0

No. 6. Leicester and Leicestershire Fund, 1933

The unexpended balance of the local fund for the Leicester Meeting in 1933, presented to the Association, the interest to be used in assisting by scholarships or otherwise students working for the advancement of science; administered by the Council.

Corresponding Figures 31st March, 1938. £ s. d.			£	
	Investments:			
	£487 2*s.* 11*d.*	3½ per cent. Conversion Stock at cost	500	
	£490 5*s.* 11*d.*	3½ per cent. War Stock at cost	500	(Value at 31/3/39,
1,000 0 0	(*Value at 31/3/38, £987 4s. 8d.*)		£1,000	£924 18*s.* 8*d.*)

Cash at bank, £9 10*s.* 7*d.*

Corresponding Figures 31st March, 1938. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1938. £ s. d.	INCOME	£ s. d.
35 0 0	To Grants paid to Committees (see Schedule)	66 0 3	34 4 2	By Interest	34 4 2
			15 10	,, Balance, being excess of Expenditure over Income for the year	31 16 1
35 0 0		£66 0 3	35 0 0		£66 0 3

Grants to research authorised but not yet claimed at 31st March, 1939, amount to £23 19 9

No. 7. Down House

In response to an appeal made in 1927 by Sir Arthur Keith, F.R.S., then President of the British Association, Mr. (now Sir) Buckston Browne, F.R.C.S., acquired the property of Down House, formerly the home of Darwin, and transferred it with an endowment to the Association as a gift to be held as a memorial to Darwin in custody for the nation.

Corresponding Figures 31st March, 1938. £ s. d.		£ s. d.	
	Investments :		
	Down House Endowment Fund		
	£5,500 India 4½ per cent. Stock, 1958/68, at cost	5,001 17 4	
	£2,500 Commonwealth of Australia 5 per cent. Stock, 1945/75, at cost	2,468 19 0	
	£3,000 Fishguard and Rosslare Railway and Harbours 3½ per cent. Guaranteed Preference Stock, at cost	2,139 17 3	
	£2,500 New South Wales 5 per cent. Stock, 1945/65, at cost	2,467 7 9	
	£2,500 Western Australia 5 per cent. Stock, 1945/75, at cost	2,472 1 6	
	£3,340 Great Western Railway 5 per cent. Consolidated Guaranteed Stock, at cost	3,436 7 5	
	£2,500 Birkenhead Railway 4 per cent. Consolidated Stock, at cost	2,013 9 9	
20,000 0 0	(*Value of Stocks at 31/3/38, £23,925 16s. od.*)	£20,000 0 0	(Value of Stocks at 31/3/39, £22,200 18s. 0d.)
	Cash overdrawn	£99 15 1	
	Cash in hand	£22 7 11	

Corresponding Figures 31st March, 1938. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1938. £ s. d.	INCOME	£ s. d.
822 8 10	To Wages of Staff	829 3 5	139 5 0	By Rents receivable	137 16 8
71 9 3	„ Rates, Insurance, etc.	72 19 1	177 8 0	„ Income Tax recovered	186 15 0
175 0 7	„ Heating, etc.	134 0 6	807 15 0	„ Interest and Dividends	789 1 6
91 13 7	„ Lighting and Drainage (including oil and petrol)	69 15 8	3 8 9	„ Donations	3 12 9
14 10 2	„ Water	14 0 8	26 8 4	„ Sale of Catalogues, Postcards and Photographs	25 19 6

428 3 1	To Repairs and Renewals	150 3 0	150 0 0	By Pilgrim Trust grant	100 0 0
61 8 5	" Land: Materials and Maintenance	90 11 1		" Instalment of Grant from Herbert Spencer Bequest	101 12 10
5 5 0	" Donations to Village Institutions	5 5 0	366 9 0		
12 5 11	" Household Requisites, etc.	11 14 7		" Balance, being excess of Expenditure over Income for the year transferred to Suspense Account	70 10 7
3 14 10	" Transport and Carriage	1 9 3			
- - -	" A.R.P.	4 13 6	50 1 2		
34 15 7	" Printing, Postages, Telephone, and Stationery	31 13 1			
1,720 15 3		£1,415 8 10	1,720 15 3		£1,415 8 10

No. 8. Herbert Spencer Bequest Fund

A gift of £1,241 from the late Herbert Spencer received during 1936, to be exhausted within 5 years and to be expended on purchase or enlargement of premises, books, apparatus or collections, or for furniture or repairs or equipment of travellers or donation of instruments of research, but in no way or degree for purposes of endowment.

Corresponding Figures 31st March, 1938. £ s. d.		£ s. d.	
	Investments :		
	£398 4s. 3d. 3 per cent. London County Consolidated Stock, 1956/61, at cost	400 0 0	
	£197 6s. 6d. 3½ per cent. War Stock, at cost	208 16 0	
723 4 3		£608 16 0	(Value at 31/3/39, £554 6s. 2d.)

Cash at bank, £23 14s. 8d.

Corresponding Figures 31st March, 1938. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1938. £ s. d.	INCOME	£ s. d.
366 9 0	To Down House—Contribution towards cost of repairs, etc.	101 12 10	20 4 0	By Interest and Dividends	19 6 0
37 19 6	„ *Contribution towards cost of office decoration*	– – –	– – –	„ Income Tax recovered	2 19 8
	„ Loss on Sale of Stock	11 6 8	384 4 6	„ Balance, being excess of Expenditure over Income for the year	90 13 10
404 8 6		£112 19 6	404 8 6		£112 19 6

Note.—Balance of original gift remaining unspent at 31st March, 1939, is £632 10s. 8d.

No. 9. Radford Mather Lecture Fund

A gift of £250 received from Mr. G. Radford Mather in 1936 to establish a Fund, the income therefrom to be devoted to meeting the expense of triennial Lectures on Recent Advances in Science and their relation to the Welfare of the Community.

Investment :

	£	s.	d.	
£248 17*s*. 8*d*. 3 per cent. London County Consolidated Stock, 1956/61, at cost . .	250	0	0	(Value at 31/3/39, £228 19*s*. 5*d*.)

Cash at bank, £7 5*s*. 6*d*.

EXPENDITURE	£	s.	d.	INCOME	£	s.	d.
To Balance, being Income for year . .	7	5	6	By Interest and Dividends . . .	5	8	2
				„ Income Tax recovered . . .	1	17	4
	£7	5	6		£7	5	6

Schedule of Grants paid to Research Committees, etc.

during the financial year April 1, 1938, to March 31, 1939

NOTE.—The year indicated in brackets after the title of each committee is that of its original appointment, and the sum, if any, is that previously expended out of grants by the Association.

	£	s.	d.	£	s.	d.
1. PAID OUT OF GENERAL FUND.						
Thermal Conductivities (1934 : £11 9*s*. 3*d*.) . .	29	11	9			
Zoological Record (1923 : £685)	50	0	0			
Bird Behaviour (1938)	40	0	0			
Sex in Salmon (1938)	25	0	0			
Freshwater Biological Station, Windermere (1930 : £562 15*s*. 11*d*.)	75	0	0			
Insular Faunas (1938)	10	0	0			
Plymouth Laboratory (1886 : £1,398 10*s*. 8*d*.) . .	50	0	0			
Density of Living Organisms (1938)	40	0	0			
Human Geography of Tropical Africa (1926 : £80 2*s*. 4*d*.)		8	6			
National Atlas (1938)	10	0	0			
Chronology of the World Crisis (1932 : £19) . . .	5	0	0			
Early Mining Sites in Wales (1935 : £1 19*s*. 4*d*.) . .	8	0	0			
Derbyshire Caves (1921 : £358 15*s*. 8*d*.) . . .	25	0	0			
Kent's Cavern (1925 : £35)	5	0	0			
Routine Manual Factor (1931 : £80)	50	0	0			
Cytology and Genetics (1936)	5	0	0			
Artemia Salina (1934 : £35)	20	0	0			
Wicken Fen (1938)	50	0	0			
				498	0	3
2. PAID OUT OF CAIRD FUND.						
Seismology (1895 : £4,720 14*s*. 8*d*.)	100	0	0			
Mathematical Tables (1913 : £1,436 5*s*. 8*d*. and below) .	151	9	11			
Kent's Cavern (see above)	5	0	0			
				256	9	11
3. PAID OUT OF CUNNINGHAM BEQUEST. (1929)						
Mathematical Tables (£2,259 3*s*. 9*d*.)				31	10	0
4. PAID OUT OF LEICESTER AND LEICESTERSHIRE FUND, 1933.						
Fens : Archaeological Excavation (1937) . . .	25	0	0			
Informative Content of Education (1937) . . .	1	0	3			
Mr. J. V. Westwood	40	0	0			
				66	0	3
5. PAID OUT OF NORWICH FUND, 1935.						
Dr. A. S. Watt : Breckland plants	21	0	0			
Norfolk Research Committee : Investigations at West Rudham	33	2	0			
				54	2	0
				£906	2	5
6. UNEXPENDED BALANCES OF GRANTS REFUNDED :						
General Fund : Committee on Cytology and Genetics .	2	11	3			
Bernard Hobson Fund : Reptile-bearing oolites Committee	7	14	6			
				£10	5	9

THE ADVANCEMENT OF SCIENCE

VOL. I No. 2 JANUARY, 1940

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NOTE ON COMMUNICATIONS TO THE SECTIONS

DUNDEE MEETING, AUGUST 30–SEPTEMBER 1

When the Dundee Meeting was brought to a close after three days, it was decided that all communications of which the delivery was unavoidably cancelled should be taken as read. Abstracts (or titles) of communications are therefore printed in these pages whether the communications were delivered or not, and references to dates and hours, as furnished in the Journal issued at the Meeting, are excluded.

INDEX

It is intended to supply an index to the four parts in each year, in the July issue.

OFFICERS AND COUNCIL OF THE BRITISH ASSOCIATION

PATRON.

HIS MAJESTY THE KING.

PRESIDENT (1940).

Sir RICHARD GREGORY, Bt., F.R.S.

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Prof. P. G. H. Boswell, O.B.E., D.Sc., F.R.S.

GENERAL SECRETARIES.

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Prof. Allan Ferguson, D.Sc.

SECRETARY.

O. J. R. Howarth, O.B.E., Ph.D.

ASSISTANT SECRETARY.

D. N. Lowe, M.A., B.Sc.

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Prof. W. G. Fearnsides, F.R.S.
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Prof. J. G. Smith.
Lt.-Col. W. Campbell Smith.
Prof. C. Spearman, F.R.S.
Dr. C. Tierney.
Prof. Sir Gilbert Walker, C.S.I., F.R.S.
R. S. Whipple.
J. S. Wilson.

EX-OFFICIO MEMBERS OF THE COUNCIL.

Past-Presidents of the Association, the President for the year, the President and Vice-Presidents for the ensuing Annual Meeting, past and present General Treasurers and General Secretaries, and the Local Treasurers and Local Secretaries for the Annual Meetings immediately past and ensuing.

PAST PRESIDENTS OF THE ASSOCIATION.

Sir J. J. Thomson, O.M., F.R.S. (1909).
Sir Oliver Lodge, F.R.S. (1913).
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Prof. Sir C. S. Sherrington, O.M., G.B.E., F.R.S. (1922).
H.R.H. The Prince of Wales, K.G., F.R.S. (1926).
Prof. Sir Arthur Keith, F.R.S. (1927).
Prof. Sir William H. Bragg, O.M., K.B.E., F.R.S. (1928).
Sir Thomas H. Holland, K.C.S.I., K.C.I.E., F.R.S. (1929).
Prof. F. O. Bower, F.R.S. (1930).
Gen. The Rt. Hon. J. C. Smuts, P.C., C.H., F.R.S. (1931).
Prof. Sir F. Gowland Hopkins, O.M., F.R.S. (1933).
Sir James H. Jeans, O.M., F.R.S. (1934).
Prof. W. W. Watts, F.R.S. (1935).
Rt. Hon. Lord Stamp, G.C.B., G.B.E. (1936).
Prof. Sir Edward Poulton, F.R.S. (1937).
Rt. Hon. Lord Rayleigh, F.R.S. (1938).
Sir Albert Seward, F.R.S. (1939).

PAST GENERAL OFFICERS OF THE ASSOCIATION.

Prof. J. L. Myres, O.B.E., F.B.A. | Sir Frank Smith, G.B.E., K.C.B., F.R.S.
Prof. F. J. M. Stratton, D.S.O., O.B.E., M.A.

HON. AUDITORS.

Dr. Ezer Griffiths, F.R.S. | R. S. Whipple.

HON. CURATOR OF DOWN HOUSE.

Sir Buckston Browne, F.R.C.S.

LOCAL OFFICERS FOR THE DUNDEE MEETING

CHAIRMAN OF THE LOCAL GENERAL COMMITTEE.

The Lord Provost of Dundee, John Phin, J.P., LL.D.

LOCAL HON. SECRETARIES
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Prof. E. T. Copson, University College, Dundee.
David Latto, Town Clerk, Dundee.

LOCAL HON. TREASURERS
Wm. Aitken, City Chamberlain, Dundee.
Quintin B. Grant, Royal Bank of Scotland, Dundee.

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Accommodation and Hospitality: George R. Donald.
Excursions: Dr. J. D. M. Ross.
Meeting Rooms: Prof. R. C. Garry.
Membership: Dr. J. A. Bowie.
Publications: R. L. Mackie.

SECTIONAL OFFICERS

The following list indicates Recorders and Secretaries in office before the Dundee Meeting : owing to the national emergency a few were prevented from being present at Dundee.

A.—MATHEMATICAL AND PHYSICAL SCIENCES.

President.—R. S. Whipple.
Vice-Presidents.—Prof. H. S. Allen, F.R.S., Dr. C. G. Darwin, F.R.S., Dr. G. W. C. Kaye, O.B.E., F.R.S., Prof. H. W. Turnbull, F.R.S., Prof. E. T. Whittaker, F.R.S.
Recorder.—Dr. Ezer Griffiths, F.R.S.
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Recorder.—Prof. J. E. Coates.
Secretaries.—Dr. H. J. T. Ellingham, Dr. L. Hunter.
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Secretaries.—Dr. H. C. Darby, D. L. Linton.
Local Secretary.—Dr. J. F. Scott.

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President.—Prof. H. O. Meredith.
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Vice-Presidents.—D. H. Bishop, Prof. A. R. Fulton, Henry Main, Prof. R. V. Southwell, F.R.S.
Recorder.—Wing-Commander T. R. Cave-Browne-Cave, C.B.E.
Secretary.—Prof. Willis Jackson.
Local Secretaries.—J. M. Hay, Dr. G. S. Steel.

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THE ADVANCEMENT OF SCIENCE

NOTES

In lieu of the customary meeting of Organising Sectional Committees usually held early in January, when the main lines of the programme for the ensuing Annual Meeting of the Association are laid down, a joint meeting of the General Committee and the Council was held this year, on January 5, at Burlington House in the rooms of the Society of Antiquaries, whose hospitality was gratefully acknowledged.

The first item on the agenda was one which normally takes the first place at the joint session of organising committees referred to above. This was the overt act of passing on the Chair of the Association by the retiring President to his successor, for the Presidency is an annual office coincident with the calendar year, a provision to which reference is made in a note on the following page. Sir Albert Seward, F.R.S., resigned the Chair to Sir Richard Gregory, Bt., F.R.S., and in doing so expressed the hope that his successor might 'continue in office until there has been what one may call a proper meeting of the Association '—a hope which the General Committee clearly endorsed.

For, in the circumstances of the moment, it appears improbable that a meeting on the usual lines will be held this year, and the Committee proceeded to debate possible future arrangements having this situation in view. They were informed that the authorities in Newcastle-on-Tyne, where the next Annual Meeting had been appointed to be held, did not now contemplate putting arrangements in hand—it could not have been expected that they should—although the Lord Mayor of the city had sent a friendly message to the effect that in the event of an early peace every effort would be made to assure a successful meeting there after all. Apart from this possibility, however, the Committee revealed a general sense that the Association should hold a meeting somewhere, abbreviated in time and of course on lines of less elaborate organisation than usual; and after full discussion the General Officers were instructed and empowered, in consultation with appropriate

sectional officers and others, to discover a suitable place for a conference of two or three days, and to prepare a programme for it. This (subject always to unforeseen circumstances) will be done, and announcement will follow in due course. And it is not impossible that the Division for the Social and International Relations of Science may exercise its power to arrange discussions or lectures apart from, as well as during, the intended meeting of the Association.

In the last war the Association intermitted two annual meetings, in 1917 and 1918—and by an unhappy coincidence the meeting in 1916 fell to be held at Newcastle-upon-Tyne, and was held there, though with difficulty, and with less than usual satisfaction to those who participated in it. It is well that Newcastle should wait, if wait it must, for happier times : meanwhile, present circumstances must not be allowed to modify the activities of the Association to a more than unavoidable extent. It was pertinent, therefore, that the General Treasurer, in presenting to the General Committee a review of the financial position of the Association, should make an appeal, which the Committee strongly endorsed, that annual members should not intermit their subscriptions. Upon the support which it continues to receive by way of membership depends the extent to which the Association will be able to discharge its function of advancing the cause of Science during, and beyond, this time of trouble.

*   *   *

It has been suggested that the Association, in various connections, makes diverse and rather arbitrary uses of the year, or years. It may seem to do so, but there are reasons, which may be worth summarising. The Association's natural year would appear to run from one annual meeting to the next, and so it does for the purposes of the Council, which is appointed by the General Committee at each annual meeting to carry on the business of the Association for the ensuing year, at the end of which (the next annual meeting) it makes its report. It is obvious also that the annual report of the Association, now distributed between the four quarterly issues of THE ADVANCEMENT OF SCIENCE, should begin with the issue (in October) next following the annual meeting the transactions of which it is its main function to record. The presidency of the Association, however, as indicated in the preceding note, runs with the calendar year. This arrangement, which dates only from 1932, has fully justified itself. It enables a new President (in normal times) to assume, as his first duty, the Chair of the joint meeting of Organising Committees which draw up the programme of the Annual Meeting over which he himself is to preside : under the former practice he assumed office only on the platform from which he was to deliver his address, having thus had little official association with arrangements for his own meeting. Lastly, the Association's financial year runs from April 1 to March 31. This again is a plan of no long standing : it was adopted mainly because the subscriptions for any one meeting are received mostly between April and the time of the meeting itself, and therefore annual accounts covering the period stated indicate the financial position relating to any given meeting more effectively than was the case when the accounting year ended on June 30.

The following address was to have been given at a meeting of the Division for the Social and International Relations of Science in the Caird Hall, Dundee, on Sunday evening, September 3, by the Chairman of the Division.

CONTACTS OF RELIGION AND SCIENCE

ADDRESS BY

SIR RICHARD GREGORY, BART., F.R.S.

RELIGION and science are the two chief factors which have influenced human development throughout all stages of civilisation : religion as the reaction to an inner impulse as to what is conceived to be sacred and arouses awe or reverence, and science as the accumulation of knowledge of the properties of natural objects—animate and inanimate—in relation to man's needs and his understanding of them through the use of his intelligence. One represents the emotional side of man's nature, as expressed in art and literature : the other—also the product of an inner urge—is the construction of a mental picture which gives acceptable form to what is known, at any stage of inquiry, about the nature and origin of things, visible and invisible. It is in the study of the heavens from these two points of view of devotion or worship and inquiry that religion and astronomy meet in celestial fields.

All religions, primitive and advanced, include three essential elements. First, there is a conception of the nature of the deity or deities in relation to man and the universe, and this, together with an account of the origin and history of the people professing the belief, when reduced to writing, constitutes the sacred literature of the belief ; or the Word of God, as represented in the Mosaic books of the Holy Bible.

The second element of religion is ritual, which prescribes the mode of approach to the deity in a form of worship.

The third is a code of ethics, which prescribes rules of conduct and in its highest development aims to bring the individual into harmony with what is conceived to be the will of God or the divine principle of the universe.

There is really no conflict between religion and science ; one is the expression of an instinct for communion with a Supreme Being ; the other is a spirit of inquiring into all things visible and invisible in the universe. Science does not set out to establish or depose any particular articles of belief or substance of faith, but to examine critically whatever comes before it in the natural world and to testify faithfully to what is seen.

The dogmatism of a few generations ago, both of naturalists and theologians, is giving way to a more liberal spirit ; and all who are searching earnestly for truth are considered to be worshippers at the same shrine. The study of

science creates a feeling of infinite greatness in all who pursue it; and though it may lead to imperfect interpretations, its motive cannot be irreligious.

Fifty years ago, the literal interpretation of the Holy Scriptures in the light of modern scientific discovery was the subject of much contentious discussion. Fuller knowledge has shown that the issues then raised were chiefly due to misunderstandings of the meaning of both religion and science. The sacred writings of the early Hebrews contain few allusions to what may be termed the scientific understanding of the universe, or of precise observations such as have been preserved in the records of other ancient peoples.

The message they convey was spiritual and not rational. All things were interpreted as testimonies to the wisdom and power of the Almighty and His goodness to man—as subjects of wonder and spiritual exaltation rather than as matters of intellectual inquiry. As a record of spiritual development, the Holy Scriptures are far in advance of the sacred writings of any other early peoples, and represent an important stage in the evolution of this side of human nature.

It is in the light of service to high ideals that science, without which we cannot live, and religion, without which most people see no meaning in life, can find a common field of action. The spirit should be that of the great French philosopher, Descartes, when he said that he studied science 'in order to learn how to distinguish truth from falsehood, so as to be clear about my actions and to walk sure-footedly in this life.'

Whether science is studied with the view of increasing natural knowledge, or with the purpose of adding to human comforts, it creates a consciousness which transfigures life. Neither it nor philosophy can, however, satisfy the religious instincts of the plain man, who requires a personal and social being to worship and constructs one out of his inner consciousness.

Sun and Sky Gods.

Even in most primitive times, knowledge of the properties of the things around him was necessary for man's existence, and mysterious characteristics of natural objects and phenomena were worshipped in fear or adoration. At the beginning of the history of civilisation, the sun and moon were given divine attributes, as well as used to mark the times of operations of life in days, months, and years. The earliest cultural contacts of science are preserved in historic records of such observances. Studies of such records in cuneiform texts show that a considerable knowledge of the stars existed in Mesopotamia so far back as the time of the Sumerians.

Researches on Mesopotamian cuneiform texts in recent years have shown that there was very considerable astronomical knowledge in the Euphrates-Tigris region so far back as 3000 B.C. or earlier. There is also evidence that even before dynastic times in Egypt the appearance of the star Sirius near the sun at sunrise was used to mark the beginning of a year. In the First Dynasty (King Menes, 3300 B.C.) there was a college of priests, physicians, astronomers and astrologers at Heliopolis; and the three Pyramids at Gizeh, built in the Fourth Dynasty, about 3000 B.C., were constructed with geometric accuracy based upon astronomical observations. In a tomb of the time of King Seti I

(1320–1301 B.C.) appears a list of planets at their upper culmination, or highest points on the meridian ; and at the time of the Roman conquest in the first century before the Christian era, the Egyptians passed on the astronomical knowledge of the East to the Roman world.

From the Pyramids and remains of great temples in Egypt, from the funerary furniture of tombs, as well as from numerous writings preserved in papyri, and inscriptions on temple walls, much knowledge has been obtained of the highly developed civilisation of ancient Egyptian times. The Egyptians possessed a vast literature of both secular and religious types, and their arts and architecture reveal remarkable experience of the properties and working of many materials. The construction of the great temples of Egypt, as described in preserved records and shown in existing remains, is of particular interest for astronomy, as well as for the study of mythology and religious belief.

One of these temples is that of Amon-Ra at Karnak, near Luxor, which, even in its ruins, is a most impressive structure. There seems originally to have been two temples on the site, the chief of which faced the sunset at the summer solstice, while the other opened in the direction of sunrise at the winter solstice. There are other solar temples in Egypt, but none of such grandeur as that at Karnak. From the entrance pylons of the temple to the inner sanctuary through various halls of different sizes and details, the axis of the temple is about five hundred yards in length and is unbroken by a single structure.

The sun as the source of all heat, light and life on the earth was the central object of religious belief in ancient Egypt and was personified and worshipped under the name of Ra, or Amon-Ra. During the reign of Amenhotep IV, otherwise known as Ikhnaton (1380–1362 B.C.), in the Eighteenth Dynasty, the sun god was worshipped as the one and only God—a belief which was, therefore, monotheistic. Amenhotep IV abandoned his name when he rejected the cult of Amon, or Amon-Ra, and adopted the new name of Akh-en-Aten, signifying ‘ The Blessed of the Disk.’ He then separated himself from the priests of Amon at Thebes and established his new capital on the east bank of the Nile. He was a heretic and a monotheist, and his reign and his heresy lasted less than twenty years, yet the really religious literature of Egypt reached its culminating point in this period. To him the sun was the visible symbol of the god Aten and not the great sun god Ra himself, who was believed to have created the hundreds of other gods worshipped by the Egyptians.

Philosophic insight as well as poetic beauty are manifest in Akhenaten’s noble ‘ Hymn to the Sun-Disk,’ which contains the following passage among others of high religious expression :

> Thou makest the seasons to preserve all that thou has created—the winter to cool and the flood. Thou has created the heavens afar, to go up into them, that thou mayest see all that thou hast made. Thou art One, but thou ridest in thy form as the living Sun, appearing, shining, giving, and returning. . . . Thou art in my heart, and none knoweth thee as doth thy son Akhenaten whom thou has designed to let comprehend thy thoughts and thy strength.

Whatever views may be held as to the origin of the religious impulse, there is no doubt that many objects and events in earth and sky have been regarded

as sacred and been worshipped as deities belonging to an external world, or because their properties or actions suggested the existence of forces other than those due to human agencies. Chief among these celestial objects is the sun, either as a physical body daily bringing life and warmth to mankind or as the personification of a deity. In a number of hymns in the *Rig-veda*, one of the four sacred texts of the Hindu scriptures, striking natural phenomena are apostrophised as characters of conscious beings, the personifications sometimes merging into one another and together being described as *deva*, or ' the shining ones.' Light in a physical sense, and associated with moral and intellectual values, inspired the lyrical poetry of Ayran settlers in India, and in one of the hymns in the *Rig-veda* the sun is addressed as follows :—

> His bright rays bear him up aloft, the god who knoweth all that lives,
> Surya, that all may look at him.
> The constellations pass away, like thieves, together with their beams,
> Before the all-beholding Sun.
> His herald rays are seen afar refulgent o'er the world of men,
> Like flames of fire that burn and blaze.
> Swift and all beautiful art thou, O Surya, maker of the light,
> Illuming all the radiant realm.
> Thou goest to the host of gods, thou comest hither to mankind,
> Hither all light to behold.
> With that same eye wherewith thou look'st, brilliant Varuna,
> Upon the busy race of men.
> Traversing sky and wide mid-air, thou metest with thy beams our days,
> Sun, seeing all things that have birth.[1]

Natural Philosophy and Religion.

From a very remote period, the Babylonians, like the ancient Egyptians, observed the position of the stars and other celestial objects, and thus laid the foundations of astronomy. These early observations were essentially of a religious and magical character, and their motive was to obtain a knowledge of future events, whether celestial or terrestrial. Astronomy was in the astrological stage of its development in the eight and seventh centuries before the Christian era, and a number of records by the royal astronomer show lists of stars, observations and calendars of that period of the Assyrian empire. Fragments of other tablets belonging to later eras show that the Babylonians studied astronomy on a scientific basis. They had no correct conception of the solar system, but had arrived at the conclusion that the motions of the heavenly bodies were governed by laws and were amenable to calculation ; they determined the time of the new moon's appearance and the periodic occurrence of lunar and solar eclipses, noted the course of the planets, and included in their observations a number of the principal constellations and fixed stars.

As the periodic appearance and position of the planets could be predicted, and particular groups of stars appeared at different seasons, it seemed reasonable to the Babylonians to conclude that events on the earth could be similarly

[1] *Hindu Scriptures*, edited by Dr. Nicol Macnicol (London : J. M. Dent & Sons, Ltd. ; New York : E. P. Dutton & Co., Inc.).

calculated and predicted. The gods or natural forces which determined the movements of celestial bodies were regarded as also ruling human nature. Human character and life history were believed to be determined from birth to death by the planets and stars, and the earth itself was considered to be the centre of the universe. Astrology and astronomy were thus combined in a single study.

Worship and Inquiry.

A certain amount of astronomical knowledge, as well as conceptions of the nature and origin of the universe, seems to have been derived by the ancient Hebrews from the Babylonians, and was probably introduced into Palestine by Abraham. The spirit of the sacred books of the Hebrews is, however, that of spiritual expression and not of scientific study. Thus, though the moon is often mentioned, and the Hebrew calendar was based upon the lunar month, there is no reference in the Bible to the monthly changes or phases of our satellite. Whatever astronomical or other natural objects or phenomena are described, are used for poetic imagery or spiritual purposes, and not for scientific analysis. While early Greek philosophers separated the study of Nature from that of personal deities, and sought for law and order in it, the Hebrews also made a clear, but different, distinction between the worship of God, and the contemplation of his works. They saw all things as testimonies to the wisdom and power of the Almighty and his goodness to man ; as subjects of wonder and spiritual exaltation rather than as matters of intellectual inquiry. The spirit is represented in the words :

> When I consider thy heavens, the work of thy fingers,
> The moon and the stars, which thou hast ordained ;
> What is man, that thou art mindful of him ?
> And the son of man, that thou visitest him ? [2]

While, therefore, there are many passages in Holy Scripture which show sympathetic observation of the phenomena of Nature, there is little in them that can be said to have much scientific significance. Notwithstanding this, it cannot be assumed that the Hebrews were less observant of natural things and effects than the peoples of neighbouring regions, though their reactions to them were purely spiritual. In the Book of Wisdom (7. 16–20) a high standard of natural knowledge is set before the mind of man, as is shown by the following extracts. The Book is, however, a late production, and the impact of Greek thought is evident in it.

> An unerring knowledge of the things that are,
> To know the constitution of the world and the operations of the elements ;
> The beginning and end and middle of times,
> The alterations of the solstices, and the changes of seasons,
> The circuit of years and the positions of stars,
> The nature of living creatures and the raging of wild beasts,
> The violences of winds and the thoughts of men,
> The diversities of plants and the virtues of roots.

[2] Psalms viii. 3, 4.

The Greeks appear to have obtained from the Babylonians the greater part of their knowledge of astronomy. In the sixth century before the Christian era, the Greek philosophers Xenophanes, Thales, and Pythagoras first opened up those veins of speculative philosophy which occupied afterward so large a portion of Greek intellectual energy. Grote, in his *History of Greece*, points out that they were the first to disenthral the philosophic intellect from all-personifying religious faith and to constitute a method of interpreting Nature distinct from the spontaneous inspiration of untaught minds. It is in them that we first find the idea of Person tacitly set aside or limited, and an impersonal Nature conceived as a subject of study. They defined the scope of natural philosophy, with its objective character and invariable laws, discoverable by a proper and methodical application of the human intellect. The Greek word *phusis*, denoting 'nature,' and its derivatives 'physics' and 'physiology,' unknown in that large sense to Homer or Hesiod, as well as the word *kosmos* to denote the mundane system, first appears in their time.

The experimental method of scientific inquiry was left out of account by the Greeks; and the only one of the philosophers mentioned whose experiments were concerned with measurements was Pythagoras. He was the first to show that there was a numerical relationship between the pitch of a musical note given out by a vibrating string and the length of the string, thus establishing the basis of the musical scale. Pythagoras was chiefly interested in these relationships as properties of numbers; and he applied the principle to the heavens, in which the planets made harmony as they moved in their spheres. We cannot hear the melody, said Pythagoras, because our ears are accustomed to it from our birth, so that we have nothing with which to compare it. This celestial concert was taught by Plato, who says in his *Republic*:

> Upon each of the spheres is a siren, who is borne round the sphere, uttering a single note; and the eight notes compose a single harmony.

Shakespeare introduced this conception of a musical cosmogony in the *Merchant of Venice* (act V, scene 1), but makes all the celestial bodies—stars as well as planets—sing together, without any suggestion of the harmonious relation of the planetary circles of movement. His words are:

> There's not the smallest orb which thou behold'st
> But in his motion like an angel sings,
> Still quiring to the young-eyed cherubins;
> Such harmony is in immortal souls;
> But whilst this muddy vesture of decay
> Doth grossly close it in, we cannot hear it.

In extending the origin of celestial music to the stars, without regard to the harmonious relationship believed to exist between the distances of the planets from the earth, Shakespeare followed Job, who wrote:

> When the morning stars sang together
> And all the sons of God shouted for joy.

The book of Job belongs to about the fourth century B.C.; and in some respects its form resembles the philosophical dialogue of the Greeks. It reveals Job as a close observer of Nature and a philosopher with acute insight and vivid power of expression.

Aratus and St. Paul.

The association of astronomical objects and events with religious and other festivals, and with theological teaching, is a characteristic of most early civilisations, and occupies attention in much of their literature. Among the astronomical knowledge taken over by the Greeks from Mesopotamia were the asterisms, the knowledge of the planets and their courses, and a method of predicting eclipses by means of the *saros*, a period of eighteen years and eleven days. Some of this knowledge had descended to the Chaldeans, from whom ultimately it came to the Roman world.

From the sixth century B.C. onwards there are frequent references by poets and other writers to legends connected with the stars. The earliest Greek work on astronomy is that of Eudoxus of Cnidus (403–350 B.C.), transmitted in verse by Aratus (*c.* 270 B.C.), who enumerates forty-four constellations. A commentary upon their works was written by Hipparchus, who was as great an astronomer as Aratus was a poet. Ptolemy (A.D. 100–178), who was the definitive authority on astronomy of the ancient world, enumerates forty-eight constellations. These constellations, with few changes, are still used by astronomers to mark the grouping of stars in the sky.

The most renowned Greek poem on astronomy is the *Phenomena* of Aratus, who also described weather portents and signs in another poem, *Diosemeia*, largely based upon works of Theophrastus. His astronomical poem was for several centuries very popular among the Athenians, who regarded it as comparable to Homer's *Iliad*. It was translated into Latin by Cicero and other authors and quoted largely by several Latin poets, especially Virgil. He was esteemed by both Christian and pagan philosophers. The apostle Paul lived in the midst of later Greek civilisation and was therefore familiar with Hellenistic literature and philosophy. During his second missionary tour, he came to Athens, where 'certain philosophers of the Epicureans, and of the Stoics, encountered him,' and Paul spoke to them of his new doctrine from the midst of Mars' hill, in the words recorded in the Acts of the Apostles (xvii. 22–28).

> Ye men of Athens, I perceive that in all things ye are too superstitious. For as I passed by, and beheld your devotions, I found an altar with this inscription, To the Unknown God. Whom therefore ye ignorantly worship, him declare I unto you.
>
> God that made the world and all things therein, seeing that he is Lord of heaven and earth, dwelleth not in temples made with hands ; neither is worshipped with men's hands, as though he needed any thing, seeing he giveth to all life, and breath, and all things ; and hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation ; that they should seek the Lord, if haply they might feel after him, and find him, though he be not far from every one of us ; for in him we live, and move and have our being ; as certain also of your own poets have said, For we are also his offspring.

There is no doubt that the poet to whom St. Paul particularly referred was Aratus, who was, like St. Paul himself, a native of Cilicia, though he lived three centuries earlier. As the poem of Aratus was a classic among the Greeks, the

audience could not fail to be impressed by St. Paul's quotation from it, though they were not convinced by the application of the words to the new doctrine. The actual words of Aratus embodied in St. Paul's address were as follows ; and if the word ' God ' is used instead of ' Jove,' the spirit of the two exhortations is clearly the same :

> Let us begin from Jove. Let every mortal raise
> His grateful voice to tune Jove's endless praise.
> Jove fills the heaven—the earth—the sea—the air :
> We feel his spirit moving here, and everywhere.
> *And we his offspring are.* He ever good
> Daily provides for man his daily food.
> Ordains the seasons by his signs on high,
> Studding with gems of light the azure canopy.
> What time with plough and spade to break the soil,
> That plenteous stores may bless the reaper's toil.
> What time to plant and prune the vine he shows,
> And hangs the purple cluster on its boughs.
> To Him—the First—the Last—all homage yield,
> Our Father—Wonderful—our Help—our Shield.[3]

Aratus described twenty constellations north of the celestial equator, the twelve constellations along the zodiac, and twelve south of the celestial equator, making forty-four in all. The poem is purely a didactic picture of the division of the heavens into regions represented in stories of Greek mythology, yet for half a dozen centuries its influence upon writers who followed Aratus was immense. We have in Aratus's exhortation the expression of a deeply religious spirit in the dedication of a poem which was otherwise of a purely scientific character, describing the division of the heavens into regions represented by stories and legends of Greek mythology.

There has always been faith in the existence of such a Power behind the universe as that to whom Aratus dedicated his poem, or as the God whom St. Paul declared to the Athenians. If religion is understood in the broadest sense as belief in a Spiritual Being, it may be said that prolonged inquiry has failed to show any authenticated instance of a people, however backward, who do not hold to some form of belief, which, though vague and rudimentary, can be deemed religious.

The Greek Legacy of Liberty of Thought.

When early Greek philosophers began to speculate upon the nature of the universe and the meaning of life, they founded the principle of intellectual freedom essential for the advance of science, literature, or any other aspect of civilised culture. They established the most precious heritage of the human race ; and to their spirit of liberty of thought in inquiring into all things—sacred, social or political—untrammelled by authority, European science and philosophy owes its chief debt. Many of the speculations seem crude in the light of modern knowledge, but they were all attempts to apply reason to the

[3] *The Phenomena and Diosemeia of Aratus*, translated into English verse, with notes, by John Lamb (London : John W. Parker, 1848).

solution of problems presented to our senses, and some have proved to be of fundamental significance.

In the opening verses of his poem, *De Rerum Natura*, Lucretius pleads with Venus to persuade her lover Mars to make ' the savage works of war to sleep and be still over every sea and land,' so that the mind can turn to philosophy and Nature in peaceful contemplation, and without control of traditional beliefs. Lucretius says that he essays ' to fashion teaching the Nature of Things ' ; and early in his poem he remarks :

> For I shall begin to discourse to you upon the most high system of heaven and of the gods, and I shall disclose the first beginnings of things—how from these nature makes all things and increases and nourishes them, and into these the same nature again reduces them when dissolved :—which in discussing philosophy we are wont to call matter, and bodies that generate things, and to entitle the same first bodies, because from them as first elements all things are.[4]

The advanced views of the Greek philosophers in the latter half of the fifth century before the Christian era did not meet with general acceptance in the time of Lucretius any more than they did in that enlightened period. Because Anaxagoras taught that the sun was a mass of flaming matter, he had to leave Athens to save himself from death ; and Protagoras (481–411 B.C.), the first of the Sophists, died when fleeing from Athens after he had been convicted of blasphemy. There was, however, no organised repression of liberty of thought ; and personal or political reasons were the causes of condemnation for impiety or disturbing teaching to the people. It was because Socrates would not cease to ' corrupt the young ' and invite public discussion of his philosophy of life that he was condemned to die. Rather than be untrue to his convictions, he accepted death ; and he justified his position in words vibrant with exalted principles :

> If you propose to acquit me on condition that I abandon my search for truth, I will say : I thank you, O Athenians, but I will obey God, who, as I believe, set me this task, rather than you, and so long as I have breath and strength I will never cease my occupation with philosophy. I will continue the practice of accosting whomsoever I meet and saying to him, ' Are you not ashamed of setting your heart on wealth and honours while you have no care for wisdom and truth and making your soul better? ' I know not what death is—it may be a good thing and I am not afraid of it. But I do know that it is a bad thing to desert one's post and I prefer what may be good to what I know to be bad.[5]

An example of Greek regard for freedom of speech and liberty of religious thought is afforded by St. Paul's mission to Ephesus, as related in the Acts of the Apostles. Cybele, the Great Mother of the Gods, whose worship began in Asia Minor and afterwards became the most popular cult in ancient Greece and Rome, had as her sacred symbol a small object which had fallen from the skies, evidently a meteorite. She was the Diana of the Ephesians whose images

[4] *Lucretius De Rerum Natura*, with an English translation by Dr. W. H. D. Rouse (London : W. Heinemann, Ltd. ; Cambridge, Mass. : Harvard University Press).

[5] *A History of Freedom of Thought*, by Dr. J. B. Bury (London, 1913).

and silver shrines were the 'gods made with hands' of the craftsmen who objected to the Apostle Paul preaching a gospel which would deprive them of their chief source of wealth. 'Ye men of Ephesus,' spoke the town clerk in appeasing the people who had cried out for two hours 'Great is Diana of the Ephesians,' 'what man is there that knoweth not how that the city of the Ephesians is a worshipper of the great goddess Diana, and of the *image* which fell down from Jupiter.'

When St. Paul preached at Ephesus, the uproar of makers of silver shrines of Diana against him was raised by Demetrius, a silversmith, who called together the workmen of like occupation to create disorder at his meeting, as men have done in much later times when their source of living seemed to be in jeopardy. The words in which the town clerk appealed to the assembly for liberty of speech afford another example of the intellectual freedom cherished in ancient Greece. After referring to the acknowledged greatness of Diana, as mentioned in the above verse from the Acts of the Apostles, he continued :

> 'Seeing then that these things cannot be spoken against, ye ought to be quiet, and to do nothing rashly.
>
> 'For ye have brought hither these men, which are neither robbers of churches, nor yet blasphemers of your goddess.
>
> 'Wherefore if Demetrius, and the craftsmen which are with him, have a matter against any man, the law is open, and there are deputies : let them implead one another.
>
> 'But if ye enquire anything concerning any other matter, it should be determined in a lawful assembly.
>
> 'For we are in danger of being called in question for this day's uproar, there being no cause whereby we may give an account of this concourse.
>
> 'And when he had thus spoken, he dismissed the assembly.'

Law and Order in Nature.

It is difficult now to realise the liberation of life and intellect brought about by the works of Copernicus, Galileo, and other pioneers of scientific learning. The very foundations of belief were shaken when the earth was dethroned from the position in which presumptuous man had placed it, and was shown to be a minor member of a group of planets revolving around a sun which was itself only one of millions of suns in stellar space.

The Holy Scriptures, together with the works of early Christian fathers and some Greek philosophers, were believed to contain the truth about all things, visible and invisible, and men used them as the final court of appeal as to what was true in Nature. When Galileo discovered the four satellites of Jupiter by means of his small telescope, the philosophers of his time would not look through the instrument to see these bodies for themselves ; for, as Galileo remarked : 'These people believe there is no truth to seek in Nature, but only in the comparison of texts.' They held that the moon was perfectly spherical and absolutely smooth, and it was in vain that Galileo appealed to the evidence of observation to the contrary. The sun was supposed to be immaculate ; therefore Galileo's observations of spots upon it were illusions. Contrary to Aristotelian teaching, two unequal masses dropped from a height were found

to reach the ground together. Though there is no contemporary evidence that the Leaning Tower of Pisa was used for a demonstration of this fact, yet, in his *Dialogues concerning Two New Sciences*, Galileo makes Sagredo say :—" But I, Simplicio, who have made the test can assure you that a cannon ball weighing one or two hundred pounds, or even more, will not reach the ground by as much as a span ahead of a musket ball weighing only half a pound, provided both are dropped from a height of 200 cubits."

When Newton had shown that his law of gravitation was sufficient to account not only for the movements of the planets but also for the paths of comets, it was no longer reasonable to believe that they were sent as signs or warnings to the human race. Consider the tremendous revolution involved in this substitution of permanent natural law for the conception of a world in which all events were believed to be reflections of the moods of a benign or angry God. The doctrine of daily supernatural intervention meant that men regarded themselves merely as clay in the hands of the potter, and did nothing to shape their own natural destiny. They accepted disease as an act of God instead of cleansing their houses, and believed that all the qualities they possessed, as well as the actions they took, were determined by the positions of the planets and other celestial bodies. Every organ of the human body was supposed to have its counterpart in the sky, and when Vesalius by his dissections, and Copernicus by his system, showed that there was no relationship between the human frame and the order of the universe, the ponderous superstructure of faith and pseudo-philosophy which had been built upon it fell to pieces and a new mental world had to be constructed. Instead of a few thousand stars supposed to exist to influence the earth and affect the purposes of man, we now know there are many millions which can never be seen without telescopic aid, and millions more that are not visible with any optical means. The universe has thus been vastly extended, and the puerile ideas of past centuries have given place to far nobler conceptions of the majesty and power of Nature. The intellectual expansion thus brought about, together with the sense of justice which resulted from the existence and permanence of law in Nature, profoundly influenced human thought and resulted in social changes which had the greatest civilising effects.

Just as Copernicus deposed the earth from the position it was supposed to occupy in the universe, so Darwin placed man in a new relationship to the rest of living creatures. Indeed, the great controversy between the evolutionists and the creationists in the second half of the nineteenth century corresponded closely to that between the Copernicans and Ptolemaists three hundred years earlier. It is often supposed that Darwinism leaves ethical and moral ideas out of consideration and stands only for the doctrine of ' Nature, red in tooth and claw ' ; but this is due to lack of understanding of the principle. Evolution embodies the idea of social ethics and makes the welfare of the community the essential purpose of the life of the creature. The view that Darwinism signifies nothing more than striving after personal or national mastery at all costs is a crude misconception of this great principle, and was repudiated alike by its founder and by Huxley, its most powerful exponent, as contrary to the best ends of civilisation.

Stimulus and Endeavour.

Unlike the creatures of the field, man can make his own environment and so promote the development of any type he desires to survive—poet, philosopher, profiteer, or pugilist. This is true of man as 'Nature's insurgent son' continually fighting against forces of evil which would destroy him, yet able to survive by the use of his intelligence. He may not know the reason for his existence, but he does know that there is law and order in the natural world and that if he breaks them the penalty is inevitable. Whether he believes that this world and the whole universe were brought into being by a Supreme Power or not, he has to obey the laws of Nature in order to survive.

If it is assumed that the divine purpose of the existence and evolution of life upon the earth is that man should work out his own salvation, it is difficult to understand what the ultimate gain will be when the earth will no longer be in a condition to maintain life as we conceive of it. All that science can say as to the future of the earth, or of any other planet or system in the astronomical universe, is expressed in the words, 'Our little systems have their day : they have their day and cease to be.' We may contemplate the progressive development of man and society to any stage that may satisfy our ideals, but, so far as we now know, the whole phantasmagoria will eventually be dissolved, and the death of mankind will be the final penalty for achieving the highest type of humanity conceived by the human mind. This thought should not, however, be subversive of effort and aspiration on the part of humanity as a whole, any more than the individual should neglect noble motive and conduct because he himself has to pass away whether his influence has been for good or evil. Though science is unable to provide convincing evidence for survival of personality after death, it must acknowledge that belief in such survival is a powerful ethical factor in human development. It is just as permissible, therefore, to assume that another world awaits habitation by an exalted type of humanity after this earth has come to an end, as it is to believe in the eternal existence of personality.

Whatever convictions may be held as to the future of man or humanity, the standard of goodness is decided by the community. The man who lives a moral life merely because he wishes to save his own soul is little better than an expectant hedonist ; for his motive is personal profit. He may be saved from punishment hereafter by being negatively evil, but his life will be of no benefit to the human race unless he is positively good. What existence awaits us when we are called away we cannot say, but stimulus and high endeavour may be found in the hope that each thread of life is intended to contribute to the web designed by its Creator. Though science may not be able to contribute much to the ultimate problems of spiritual beliefs, it does teach that every action carries with it a consequence—not in another world, but in this—to be felt either by ourselves or by others in our own time or the generations to come.

We have passed the stage when, in order to afford support for Christian belief in general, and the Mosaic account of creation in particular, it was only necessary to find naturalistic or rationalistic explanations of miraculous and other elements in biblical records. Such attempts to fit all new knowledge into a system of thought having no claims to scientific accuracy or intention served no useful purpose to the Bible or to science, and to-day would satisfy

neither historical students nor naturalists. A much sounder basis can be found by applying evolutionary principles to religious thought, and by studying sacred books as stages in the story of man's progressive discovery in theology. It is only by disregarding history that the idea of a fixed and final theology becomes possible. In science, there are no final interpretations or unchangeable hypotheses ; and when the same principle is recognised in theology, religion will share some of the vitality of the natural sciences. Evolution can be regarded by the theologian as merely the means of creation ; and the conception of gradual development is not incompatible with Christian theology. It is through the acceptance of the idea of evolution in the spirit as well as in the body of man that the partition which formerly separated religion and science is being dissolved.

INSTRUMENTS IN SCIENCE AND INDUSTRY

ADDRESS TO SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES

By ROBERT S. WHIPPLE

PRESIDENT OF THE SECTION.

I FEEL that it is a great honour to be chosen as President of Section A, particularly because on looking through the names of my distinguished predecessors I find that I am the first professional maker of scientific instruments to occupy this Chair. My immediate predecessor, Dr. C. G. Darwin, who now occupies the important position of Director of the National Physical Laboratory, gave us at Cambridge a brilliant dissertation on the use of mathematics in solving physical problems, and the need of the mathematical outlook when facing a series of facts requiring solution. He would, I am sure, be one of the first to insist that the mathematician requires physical facts to enable him to develop a physical theory, and that the probable soundness of the theory will depend largely upon the accuracy of the data discussed. In the majority of cases this accuracy depends on the qualities of the apparatus employed in the observations, assuming that the observer is fully qualified and capable of obtaining the best results from it. I believe that all such observers now demand far more from their apparatus than was formerly possible, but few realise the amount of thought and labour involved in raising the accuracy obtainable from one to one-tenth of one per cent.

The help that instruments have given to the advancement of science is a fascinating theme, and at the same time a wide one. Amongst the earliest and most striking examples we find that Kepler was able to state his Laws of Planetary Motion as a result of the observations made with Tycho Brahe's carefully constructed instruments. Tycho (1546–1601) first introduced (though

he did not discover) the method of transversal division of the arc, which is now familiar to us as the basis of the diagonal scale. It was he who first pointed out the importance of symmetry in an instrument. The ingenious naked-eye sights developed by him were a remarkable improvement on the simple sights previously used. According to Dreyer [1] his determinations of the right ascensions and declinations of his nine standard stars show a probable error of less than thirty seconds of arc—an almost incredible achievement.

I propose to consider a few well-known instruments and to use them as examples to indicate how the development of a particular subject has grown largely with the perfection of the instruments used to investigate it. It is in every way a reciprocal process. By means of an instrument certain evidence is obtained; this evidence does not go far enough and the instrument must be improved to enable further facts to be found. If, for example, the biologist requires to examine small bodies beyond the range of his microscope, he appeals to the physicist to help him, and the appeal is not in vain. Most probably, as a result of the work on his colleague's problem, the physicist develops a technique which will be of service either to him or to a fellow-physicist.

As examples of instruments primarily used to extend the range of our senses I will take the microscope, telescope and spectroscope. Their development has a long history, and each can be adapted to yield accurate measurements by the addition of suitable devices. Thus we are led to the application of the mechanical arts to the division of angles and lengths in dividing engines and the measurement of time by various appliances which may be considered as supplementary to those first mentioned. To exemplify classes of instruments whose use rapidly extended from the laboratory to the industrial field I will review those employed in temperature measurement including the galvanometer, and, as an example of the rapid application of new physical knowledge by the instrument maker, the thermionic valve as applied to measurement.

The first example I shall take is the microscope, an instrument which is used in every observational science and, in some form or another, in nearly every industry. The early story of the microscope has been often told, and yet it may be of interest to recall the most important stages in its development. The first instruments consisted of single lenses, actually small globules of glass, which, when the surfaces were suitably ground, yielded in the hands of skilled observers surprisingly good results. The outstanding example is the Dutch naturalist Leeuwenhoek, who during the period 1674–1723, using a microscope of this type, discovered the protozoa and bacteria, and made many other biological observations of supreme importance.

Hooke, who was Leeuwenhoek's correspondent, was working at microscopical problems at the same time, and in the *Micrographia* (1665) described his own microscope—the first compound microscope. The optical system of this instrument consisted of a converging lens, called the object-glass, the field lens, and a third lens, the eye lens. Although it has been stated frequently that Hooke first introduced the field lens to enlarge the field of view, there is little doubt that this invention was due to Monconys, who published a short description of a compound microscope made to his design in 1660. This hardly detracts from the credit due to Hooke, whose publication became so generally

[1] J. L. E. Dreyer, *Tycho Brahe*, p. 351 (1890).

known, and whose optical system was universally adopted and remained practically unchanged for over a hundred years.

Hevelius, in 1673, described in his *Machina Coelestis* a screw-focusing adjustment that he had fitted to an instrument of the Hooke type which was the forerunner of the modern mechanism adopted (or invented independently) by John Marshall (1663–1725), one of the great opticians at the close of the seventeenth century. Marshall should be remembered by the fact that he was the first to introduce the method of grinding a number of lenses simultaneously, by cementing a number of pieces of glass on to the surface of a large convex spherical block, and working them with a concave spherical tool. This is still the method employed for polishing lenses in quantity. In the modern spectacle lens factory as many as 150 are sometimes polished in one block.

Although many variations in the design and mechanical construction of the microscope were made during the eighteenth century and the early years of the nineteenth, yet there is no invention of fundamental importance to record until the construction of the achromatic objective. This was first successfully completed by the French optician Chevalier about 1825 and in England by Tulley working about the same time to the designs of Joseph J. Lister, nearly sixty years after the construction of a successful achromatic telescope objective.

Abbe carried the corrections of the aberrations to a far higher degree of perfection notably by using glasses of new types which at his suggestion had been worked out by Schott, to produce, about 1886, the so-called apochromatic objective in which the colour correction was greatly improved.

It is difficult to see how the resolving power of the microscope is to be further increased using light from the visible region of the spectrum. The biologist, and particularly the medical man, is anxious to study organisms the structure of which is too fine to be resolved by any object glass when using ordinary white light, the alternative to which is the employment of rays of shorter wave length, viz., the ultra-violet. Glass lenses are opaque to these short wave lengths, and therefore lenses made of fused quartz must be used. J. E. Barnard, who has developed a very successful technique in connection with ultra-violet microscopy, has shown that it is possible to study and photograph living bacteria, which are normally transparent to light from the visible region of the spectrum, without staining and therefore killing them. The use of such short wave lengths has necessitated the construction of extremely rigid mountings in the microscope body and complete absence of play in the moving parts of the instrument. As showing the perfection of the technique obtained with ultra-violet microscopy, it may be mentioned that it is possible to take a series of photographs of an object in successive parallel planes separated by distances of the order of 0·0002 mm.[2]

The use of short wave radiations has proved so successful in the case of the ultra-violet microscope that a technique has been developed which offers great possibilities for the use of still shorter radiations. As is well known, a beam of cathode rays can be brought to a focus by passing the beam through a magnetic or electrostatic field, in a manner very similar to that in which light

[2] L. C. Martin and B. K. Johnson, 'Ultra-violet Microscopy,' *Journal of Scientific Instruments*, V, p. 337 (1928); and VII, p. 1 (1930).

is brought to a focus by a convex lens. In the same way, an electron image of a surface may be formed owing to the fact that the electrons will be scattered by an amount depending on the density (or mass concentration) of the surface on which they impinge. By forming the image on a fluorescent screen it can be rendered visible, or if projected on to a sensitised plate photographically recorded.

In an instrument designed by Von Borries and Ruska,[3] an electron stream is passed through two specially designed electro-magnets (or magnetic lenses), mounted one above the other, which act as equivalents to the objective and eye-piece of an optical microscope. If an object is placed between the poles of the lower magnet some of the electrons will be scattered by the material of the object and others will be diverted by the magnetic flux so as to form an image of the object in a plane below the magnet. That an image can be formed in this way depends upon the fact that the scattering is proportional to the mass concentration at different parts of the object. The scattering will be greater from the thicker parts than from the thinner ones, and thus the dark parts of the image will correspond to the thick parts of the object, and *vice versa.* Magnifications of about twenty times those obtained with the optical microscope can be obtained. Excellent photographs have been taken of bacteria and bacilli at magnifications of 10,000 and 20,000 diameters.

In 1854, Jabez Hogg, in his introduction to *The Microscope*, states : ' It is not many years since this invaluable instrument was regarded in the light of a costly toy ; it is now the inseparable companion of the man of science.' In the same preface he mentions that in 1841 the Council of the Royal College of Surgeons had determined ' to form a collection of preparations of the elementary tissues of both animals and vegetables, healthy and morbid, adapted to illustrate the uses and results of microscopical investigations.'

It is in medical science and the sciences allied to medicine that the greatest use for the microscope is still found. In the study of zoology, physiology and botany it is essential ; but it is only when its employment in the pathological laboratories of the world is visualised that its importance is clearly understood. A microscopical examination frequently settles the question of the type of disease from which a patient is suffering, and in the whole story of hospital practice there is no spectacle more dramatic than that of the surgeon suspending an operation to await the result of the pathological examination of a tumour suspected of malignancy.

Sorby, in 1864, was the first to investigate the structure of metals and alloys by the microscope, and although it was some considerable time before his work was appreciated, there is now no metallurgical laboratory worthy of the name that does not possess a microscope by means of which the molecular structure of an alloy can be examined and photographically recorded. How important this side of the work has become is shown by the fact that the majority of scientific papers dealing with problems connected with alloys are illustrated by micrographic prints.

Although the discovery of the telescope ante-dated that of the microscope,

[3] Bodo von Borries und Ernst Ruska, ' Vorlaüfige Mitteilung über Fortschritte im Bau und in der Leistung des Ubermikroskopes' *Wissenschaftliche Veröffentlichungen aus den Siemens-Werken*, 17, p. 99 (1938).

in its service to mankind it ranks as second to it. The credit of the invention of the telescope must go to a Dutchman, Lippershey ; yet it was Galileo who first produced an instrument worthy of the name. He ground and polished his own lenses, and in 1610, with a telescope magnifying thirty-three diameters, discovered the satellites of Jupiter. Amongst his many astronomical observations he discovered the phases of Venus, and estimated the height of the lunar mountains from the length of their shadows.

Newton pointed out that the focal length of the refracting telescope could not be reduced owing to the refrangibility of light of different colours, and that it was not possible to focus for all the colours simultaneously and thus obtain a sharp image. He measured and calculated the distance between the foci of the red and violet and showed that it was about 1/50th the diameter of the lens. It was to overcome this difficulty that the glasses were made small and of long focal length. It is almost unbelievable that James Bradley, in 1722, measured the diameter of Venus with a telescope having a focal length of 212 ft.,[4] the supporting mast being about 45 ft. long.

In 1663, James Gregory suggested the construction of a reflecting telescope, and in 1668 Newton constructed the first practical instrument, having made his own alloy for the mirror and having devised methods for grinding and polishing it. A sentence in his *Opticks* (Bk. I, Pt. 1, Prop. VI, p. 75) shows how serious the position had become : 'Seeing therefore the improvement of Telescopes of given length by Refractions is desperate ; I contrived heretofore a Perspective by reflexion, using instead of an Object Glass a concave Metal.'

The manufacture of satisfactory reflectors was very difficult, and it was not until an instrument maker, James Short of Edinburgh, about 1730, produced instruments with parabolic figuring, that the reflector came into general use. His instruments, even now, may be regarded as examples of first-class workmanship.

Sir William Herschel began making specula in 1774 and constructed a large number of reflecting telescopes, the most famous being his instrument at Slough of 4 ft. aperture and 40 ft. focal length ; this was completed in 1789. Unfortunately the weight (25 cwt.) of the large speculum rendered it liable to distortion and it is of interest to note that all Herschel's discoveries were made with smaller instruments. More than fifty years later a reflector of 6 ft. aperture and 54 ft. focal length was erected by Lord Rosse at Parsonstown. All these instruments were fitted with metal mirrors which had an unfortunate tendency to tarnish, and re-polishing was apt to spoil the figuring of the mirror. In the modern instrument the metal mirror is replaced by glass which can be re-silvered at intervals. During the last few years aluminium has taken the place of silver as the reflecting surface, the aluminium being deposited on the glass surface under vacuum. The aluminium film does not tarnish, is more robust than silver and has a higher coefficient of reflection for short wave lengths, and is thus more efficient photographically.

Owing to the increasing demand for telescopes of higher magnification,

[4] The actual observation reads :
'1722
'Dec. 27. 5 h. the distance between the horns of Venus was observed 29 rev. = 57·8 in a telescope of 212¼ f. — m. diam. 19.04″.'
The Miscellaneous Works and Correspondence of the Rev. James Bradley, p. 354.

and of increased light-gathering power, the size of the mirrors used in the modern instruments is steadily increasing. The Mount Wilson Observatory has a telescope with a mirror 100 in. in diameter, and it is a matter of common knowledge that magnificent photographs of nebulæ, etc., have been obtained with it. At the present time an instrument having a mirror 200 in. in diameter is being constructed for the Mount Palomar Observatory. The manufacture of the borosilicate glass (pyrex) block for this mirror, which weighs twenty tons, has been a feat of considerable skill, and if it is successfully ground and polished, as appears likely, it will be a great engineering triumph. It is difficult to realise the accuracy of grinding and polishing required in these large mirrors. Dr. Spencer Jones, the Astronomer Royal, has stated [5] that in the case of the '100 inch mirror, made at Mount Wilson, the actual curve of the glass nowhere differed from the correct theoretical curve by more than 0·000003 inch. The precision of figure required and attained can perhaps best be appreciated if expressed in this way: suppose the mirror to be enlarged 250,000 times so that the radius of curvature becomes about equal to the radius of the Earth—4,000 miles. The diameter of the mirror would be about 400 miles and the mirror would easily cover England and Wales. The depth of its concave surface would be about five miles; the greatest difference between the paraboloid and the nearest spherical surface would be about 21 feet, and the largest divergence of the finished surface from a true paraboloid would be only about $\frac{3}{4}$-inch.' We have become so accustomed to success in mounting and operating these large telescopes, that we are apt to forget that this is the heaviest and certainly the most impressive side of instrument construction work.

Thus, for the large telescope the reflector has established itself as the most satisfactory instrument, whereas for the smaller telescope, and for the everyday purposes of life, the refractor is still the more efficient. In 1733, Chester Moor Hall found that by combining lenses made from glasses having different refractive indices he was able to correct for the unequal refrangibility of light of different wave lengths, and succeeded in making lenses which produced images free from colour. The same discovery was made independently by John Dolland, who, in 1758, produced an achromatic telescope in which the object glass consisted of a convex lens of crown glass combined with a concave lens of flint glass. The invention of the achromatic lens must be considered as one of the milestones in the development of scientific instruments—its importance in nearly every piece of apparatus employing a lens can hardly be exaggerated.

Perhaps there is no instrument which in recent times has aided pure science so much, and which is now beginning to help industry, as the spectroscope. Fraunhofer constructed the first spectroscope in 1817, and made the first measurements of the lines of the solar spectrum. He was also the first to observe the spectrum of the electric spark. In 1842, Becquerel and Draper independently photographed the solar spectrum on daguerreotype plates, thus laying the foundation for the modern science of spectroscopy.

In 1859, Kirchhoff showed that the luminous vapour of a metal has the property of absorbing the same kind of light as it emits at the same temperature. Kirchhoff recognised the fundamental importance of his discovery, entitling

[5] *Journal of Scientific Instruments*, XII, p. 39 (1935).

it 'Spectrum Analysis'; but it is largely due to Hartley (1882) and later to Twyman who designed simple and efficient instruments, that spectroscopic analysis has become a quantitative method of chemical analysis. The spectrograph is now one of the most important tools in the metallurgical and chemical laboratory. In the manufacture of steel it is proving an invaluable check on the quality of the materials; the spectrogram obtained from the sample under test being compared with that taken from a standard. The speed of analysis may be judged from the statement [6] that it is possible for one man to analyse twelve samples of nickel-chromium-molybdenum steel spectrochemically for the elements silicon, manganese, nickel, chromium, molybdenum, vanadium, aluminium and copper in less than one day. The spectroscope has also become a tool in common use in the steel warehouse, the storekeeper being able by its means to detect any mixing of the batches of steels. In the laboratories of the works producing non-ferrous materials the spectroscope is proving equally efficient. For example, the failure of lead pipes from causes other than frost has been considerable, and has been traced to impurities in the lead. A spectroscopic examination of the pipe that has failed shows in a few minutes the undesirable impurities present, and, if the examination is carried further, the quantities of those impurities. There are few trades in which the spectroscope cannot be of service in testing the qualities of materials, etc.

Our knowledge of the constitution of the celestial bodies is almost entirely due to the spectroscope. By its means it has been possible to discover what elements are present in the vapour surrounding them. This was strikingly shown by the discovery by Lockyer, in 1868, of an unknown gas (Helium) in the bright-line spectrum of the sun's atmosphere, which was identified by Ramsay twenty-seven years later in the terrestrial atmosphere. The photographing of the sun's disc in a limited band of wave lengths has led to the development of a special form of recording spectroscope, the photo-spectroheliograph. In this instrument the slit of a spectroscope is slowly traversed across the sun's image, the selected radiation falling upon a photographic plate. Thus a picture of the sun is built up from a series of photographs taken in the selected wave lengths. For example, if the wave length selected is one of calcium, a picture of the disc is obtained showing the distribution of calcium over the sun's surface. In order that the photograph should not be striated, it is essential that the movement of the spectroscope across the sun's image should be uniform. Horace Darwin obtained this result by mounting the carriage of the instrument geometrically on large balls and by moving it by a falling weight controlled by an oil cylinder. The result was a triumph of simple geometric design. The major part of the knowledge obtained about the double stars and also the determination of the velocity of stars in the line of sight has been obtained from spectroscopic observations. The theory of the expanding universe may be said to rest on spectroscopic observations.

In theoretical physics the value of spectroscopic work cannot be exaggerated; it is, I understand, true to say that modern theories of atomic structure depend largely on evidence supplied by the spectroscope. Unfortunately there is no time to dwell on the comparatively new development of the

[6] F. G. Barker, 'Some Applications of the Spectrograph to the Quantitative Analysis of Ferrous and Non-ferrous Metals,' *Journal of the Iron and Steel Institute*, 139, p. 244 (1939).

X-ray spectroscope and the importance of this instrument in chemical analysis and in the understanding of the structure and behaviour of alloys.

The distinction between the telescope suitably mounted to survey the heavens and that used to measure distances upon the earth's surface is a faint one. The transit instrument is in general only a larger form of theodolite. The early surveyors (and here we may go back to early Egyptian times) made plans by means of rods and plummets ; but it was not until the invention of the astrolabe and the use of a divided circle fitted with sights that accurate surveying was attempted. The first mention of the word ' theodolite ' occurs in a book *Pantometria* (1571) by an Englishman, Thomas Digges. (It is a matter of interest that Digges has some claim to be called ' the inventor of the telescope.') The early theodolites, like the astronomical instruments, were fitted with pin-hole sights : in the case of the latter instruments an important controversy arose between Hooke and Hevelius (1679) concerning the relative advantages of telescopic and open sights. Although Hevelius was not convinced, the telescopic sight was almost invariably used after that date. Mention should be made that William Gascoigne invented the filar micrometer and fitted it to a telescope in 1640 : this invention greatly increased the accuracy of instruments to which it was attached. Bradley's observation in 1722 shows that he used a form of filar micrometer with considerable success.

As the demands of the astronomer (and later of the surveyor) increased, so the need for improved divided circles became more urgent. The accurate dividing of circles has always been one of the more difficult tasks of the instrument maker, and it is almost entirely due to the English manufacturer that the art of dividing has reached its present high position. For many years there was no alternative but patiently to bisect, or trisect, with a beam compass the spaces set out on the scale or circle, and to continue this operation until the scale was subdivided to the desired number of divisions. The master points controlling the dividing can even now be seen on some of the old instruments. The names of George Graham (1673–1751) and John Bird (1709–1776) may be mentioned as masters of the art : it is stated that Bird was able to obtain an accuracy of 5 minutes of arc on his 8-ft. quadrant by continued bisection of the arc.

Henry Hindley of York, about 1739, completed a small machine for cutting the teeth in clock wheels and for dividing instruments. In 1766 Jesse Ramsden made his first circular dividing engine, but as it was not sufficiently accurate for dividing the scales of nautical instruments, he completed a second machine in 1775. As this was the pioneer of the modern dividing machine, it may be of interest to describe it in some little detail. The machine is now in the United States National Museum at Washington.

It consists of a horizontal wheel or plate 45 in. in diameter, which turns on a vertical axis. The periphery of the wheel is cut or notched into 2,160 teeth, into which a worm meshes. Immense care was taken over the cutting of the teeth. The wheel was first divided into five parts, and each of these into three ; these parts were then in turn bisected four times : this gave spaces corresponding to 432, 144, 72, 36, 18 and 9 teeth. These in turn were checked with another circle divided by continual bisections. The downward stroke of a treadle turned the screw forward a definite amount as determined

by suitable mechanism. The circle to be cut was centred and fixed to the master plate, and after each stroke of the treadle a division was cut by hand, the cutting point being carried in a frame which would allow of linear motion only. One forward revolution of the screw advanced the plate through 10 minutes of arc.

(It was with this machine that Ramsden divided the circles of the 3-ft. theodolites used in the principal triangulation of Great Britain and Ireland, 1792–1862. They were divided to 10 minutes and read to one second by three micrometer microscopes.)

In 1826, William Simms invented the self-acting mechanism by means of which the dividing machine became completely automatic, thus saving an immense amount of time, and reducing the risk of error in the dividing of a circle. A similar but larger machine, built by G. W. Watts in 1905, is capable of dividing a circle 4 ft. 6 in. in diameter to 30 seconds of arc with an error not exceeding $\pm$ 1 second.

Linear scales are automatically divided by somewhat similar machines in which are fitted a temperature compensation device for variation in the temperature of the machine and a compensation device for correcting for any variations in the pitch of the master screw. In this connection the scientific man and the instrument maker are alike indebted to the late Dr. C. Guillaume for the invention of 'invar,' a nickel-steel alloy having a remarkably small temperature coefficient of expansion, and hence an almost ideal material from which to manufacture standard scales and measuring tapes. In the case of linear scales the position of the lines in a good metre scale can be guaranteed to an accuracy of 0·002 mm.

An interesting development in surveying instruments has taken place during the last few years. Heinrich Wild, a Swiss engineer, designed about 1921 a theodolite in which by means of an ingenious optical system it is possible to read the positions of the vertical and azimuth circles simultaneously in the eye-piece of a microscope mounted on the same axis as the telescope The optical system for reading the circles demanded that they should be divided on glass, and the observer on his part insisted that the weight should be reduced. In the case of an instrument intended for a triangulation of the first order, the horizontal circle is 5·5 in. in diameter, and it is divided to 4 minutes of arc. The final readings are taken on a micrometer drum and may be relied upon to 0·1 second. The dividing is etched on the glass, the thickness of the lines and figures not exceeding 0·0006 in. (0·015 mm.), the divisions being about 0·003 in. (0·075 mm.) apart. I may here interject that the obtaining of a resist that would allow the etching on the glass of such fine and close lines by an acid has necessitated a great deal of research. It may be regarded as typical of one of the small but serious difficulties that the instrument maker has so often to solve. The weight is about one-third that of any other type of instrument of similar accuracy, and the time taken over an observation at least one-quarter. Divisions etched on glass are more stable than those cut on silver, and the dividing error is reduced by the fact that circles do not have to be 'cleaned off' after dividing, and thus there is no risk of distorting a line. In this connection it may be of interest to mention that the new reversible transit circle at the Greenwich Observatory, just completed by Messrs. Cooke, Troughton and Simms, is fitted with glass circles 28 in. in

diameter, the divisions being etched at intervals of 5 minutes of arc. The Astronomer Royal informs me that the extreme range in the division errors is only about 0·75 second and that the error of reading is very small.[7]

Before leaving surveying instruments mention must be made of the new developments in aerial surveying in which contours, etc., are obtained from photographs taken from aircraft at different standpoints. Although surveying by photography had been used before the Great War for the mapping of districts difficult to survey by ordinary methods, yet it was not then generally employed. Improvements in photography from the air, especially in the development of wide angle flat field photographic lenses having negligible distortion up to an included angle of 90°, have made it economically possible to survey fresh country, and even to check-over surveys that have been previously made by the usual methods. The ever-changing outlines of our towns can now be accurately recorded by photographs taken from the air. As an example it may be mentioned that with a Ross 4-in. lens photographs have been taken over London from a height of 22,000 ft., representing over 40 square miles on a plate 7 in. square. The distortion given by such a lens is exceedingly small, a point in the image plane not being more than $\pm$ 0·01 mm. out of its correct position, except on the edge of the plate where the distortion slightly increases but does not amount to 0·1 mm. A new development, and one of great promise, is the construction of a multiple lens camera. Major-General M. N. MacLeod recently described [8] the performance of a seven-lens camera, comparing it with the results given by a single-lens instrument. He stated that at a flying height of 15,000 ft. the area of the picture obtained with the seven-lens was 96 square miles as compared with 8·4 square miles with the single lens, and that the number of photographs required to obtain a survey of 1,000 square miles was 32 as compared with 410; an immense saving in flying time. Several forms of plotting machine have been developed for the interpretation of the photographs obtained, the majority combining either stereoscopically or otherwise the two views taken from different standpoints. One of the most successful of these has been designed by Captain E. H. Thompson of the Ordnance Survey. The results obtained with the air survey plotting instruments have proved not only more accurate but more expeditious than surveys made on the ground.

The earliest of all instruments were, however, those devoted to the measurement of time, and depended on the position of the sun; in the majority of cases on the position of a shadow cast by it. Later the time was also told by observing the position of the earth relative to the stars. Throughout the Middle Ages, and later during the fifteenth to seventeenth centuries, great ingenuity was shown in the design and construction of sundials and nocturnals. The large literature on the subject shows how important the measurement of time was, even then, to the community. For the purpose of our discussion

[7] He also states that 'The principal contributory causes to the total probable error of a single observation of declination are (*a*) error of bisection of star by declination micrometer wire; (*b*) error in assumed refraction; (*c*) slow wandering of star image produced by atmospheric irregularities; (*d*) errors in adopted instrumental errors of level, azimuth, etc., which vary with changes of temperature and direction of wind, and which are interpolated from smoothed curves.'

[8] M. N. MacLeod, 'Some Recent Developments in British Surveying Instruments,' *Proc. Phys. Soc.*, 51, p. 716 (1939).

we need not dwell further upon these instruments nor upon the clocks used previously to the invention of the pendulum. Although Galileo had noticed in 1581 that the time of swing of a pendulum was almost independent of the amplitude of its swing, yet it is doubtful whether he succeeded in making a working clock. In 1657 Huyghens patented his pendulum clock, and described it fully in 1673 in his *Horologium Oscillatorium.* The clock was driven by a falling weight and kept the pendulum in motion by impulses transmitted through a verge escapement. Shortly after this date Hooke invented the anchor escapement, which, in its form modified by Graham, became the escapement used in the majority of pendulum clocks, and remains so to the present day. The effect of temperature upon a pendulum clock is serious, in that the length of the pendulum varies with temperature and hence the duration of the period of swing. Graham in 1721 introduced a pendulum bob containing mercury ; thus, by adjusting the quantity of mercury its expansion could be made to counteract that of the steel pendulum rod. Five years later Harrison invented the composite, or ' grid-iron,' form of pendulum made of brass and steel rods to which the weight was attached. Nearly all the temperature compensation difficulties disappeared with the invention of invar, a material of negligible temperature expansion-coefficient. There is not time to enlarge upon the devices for compensation for changes in barometric pressure and on the various methods for maintaining a standard clock in motion. Mention must be made of the Shortt free pendulum clock introduced in 1921, in which the daily variations in the rate are only a few thousandths of a second.

In the history of timekeeping the chronometer of Harrison must be mentioned as it marked a great step forward as compared with its predecessors. In the official tests of his fourth instrument it was shown that over a period of five months on a voyage to Barbados and back its total error was fifteen seconds. About 1920 Guillaume introduced an alloy, *elinvar,* whose elasticity is almost independent of temperature, and it is also non-magnetic. Thus by making the balance wheel of a watch or chronometer of this material, the effects of temperature and stray magnetic fields have been eliminated. Official tests show that a watch fitted with a Guillaume balance, which in this case is a cut balance of brass and 42 per cent. nickel-steel alloy, may have a mean variation of daily rate of only 0·06 second.[9]

The accurate control of the length of the wireless waves radiated by the broadcasting stations has been a difficult problem, and has resulted in the production of an extremely accurate timekeeper. That certain asymmetric crystals when subjected to electrical stresses change their dimensions was discovered by the brothers J. and P. Curie in 1880. They also showed that such crystals develop surface charges under the influence of mechanical pressure. Later it was shown that when stressed by a rapidly alternating current the crystal is made to vibrate, and if the frequency agrees with the natural frequency of the crystal the amplitude of oscillation is relatively large. Primarily owing to the work of two men, W. G. Cady in America and the late D. W. Dye in this country, quartz crystal controlled oscillators have been developed which maintain themselves in oscillation at a definite frequency and with an accuracy of approximately one part in one hundred million. A form of clock has been designed in which the maintaining power is an electric circuit controlled by

[9] *The National Physical Laboratory, Watch and Chronometer Trials,* p. 7 (1938).

a quartz oscillator. One of these clocks has been installed at the Royal Observatory, Greenwich, and it is hoped that by its means it may be possible to check the time of rotation of the earth upon its axis. I think it would be difficult to find a more striking example of a piece of pure scientific research work developing into an appliance with almost unlimited possibilities.

From the point of view of industry, the thermometer is one of the most important of all scientific tools, for that is its ultimate position. There is hardly an industry in which temperature does not play an important part, and in our daily lives the question of the temperature of our bodies, or of the air surrounding them, is of fundamental importance.

The first instrument for measuring temperatures was an air-thermometer, and was invented by Galileo about 1592. His friend Sanctorius actually used a form of thermoscope to show variations in the heat of the human body—the first clinical thermometer. The Grand Duke Ferdinand II of Tuscany is said to have invented about 1650 the first alcohol thermometer in which the tube was hermetically sealed. It is not known to whom the invention of the mercury-in-glass thermometer is due, although they were in existence in 1693.

Lord Kelvin propounded the thermo-dynamic scale of temperature as the final standard of reference, and it is to this scale (the absolute scale of temperature) that all temperatures are now referred. The National Physical Laboratories of the world have, at immense trouble, linked up their thermometric scales, so that readings taken by an instrument standardised by the Bureau of Standards in Washington will be found to agree with those certified at the National Physical Laboratory. The first important work of this kind was an investigation at the Bureau International des Poids et Mesures, about 1884, into the errors of mercury-in-glass thermometers. As a result it was shown that if the thermometer bulb was made of a ' hard ' glass, and if a carefully prescribed routine was followed in the standardisation of the thermometer, it could be made an instrument capable of measuring temperatures throughout its range to 0·001° C.

The recent developments in the manufacture of mercury-in-steel thermometers and of vapour pressure thermometers have largely reduced the demand for mercury-in-glass thermometers in industry. That there is still a huge field for the mercury thermometer may be judged from the fact that the National Physical Laboratory certifies over half a million clinicals annually, and that air temperatures are largely taken with such thermometers.

Electrical methods of measuring temperature have made great strides during the past few years. A great deal of this progress was due to the work of H. L. Callendar, who was President of Section A when the British Association last met in Dundee in 1912. He showed that the resistance thermometer suggested by Sir William Siemens in 1871 could be made an instrument of high precision and at the same time developed simple bridge methods for measuring the resistance of the thermometer. Above all he invented the Callendar Recorder, the pioneer of the majority of recording bridges and potentiometers in use to-day. Callendar possessed in a marked degree the gift of explaining difficult problems, and also that of great experimental skill.

Although the resistance thermometer is still the standard for the range −100° to 600° C., it is not used as frequently in industry for the measurement of high temperatures as it was a few years ago. Its industrial field has become

that covering temperatures below 500° C., and more particularly for use in positions where by means of a switchboard it is convenient to read a group of temperatures from one central position.

The discovery of thermo-electricity by Seebeck in 1822 led eventually to the production of the simplest electrical thermometer and one of the most practical in industry. The platinum, platinum 10 per cent. rhodium couple was introduced by Le Chatelier in 1886, and owing to its reliability and to the fact that its electrical constants can be reproduced in various meltings of the alloy, has become the most generally used in accurate high temperature work. Owing to the high price of platinum this thermo-couple (generally referred to as the 'rare-metal' couple) cannot be used in industry as freely as one would wish, but the invention of the 'base metal' couples, such as iron, constantan (Ni 40 Cu 60 per cent.), nickel, nickel-chromium (Ni 90 Cr 10 per cent.), has largely met the requirements. The latter of these two couples, due to Hoskins, may, if suitably protected, be used for temperatures as high as 1200° C. The base metal couples yield a high E.M.F., thus tending to simplify the measuring equipment.

A variety of potentiometers, deflection galvanometers and recorders have been developed to meet the demands of industrial thermometry. It is, I think, true to state that with very few exceptions no heat treatment is now given to any material in a manufacturing plant without thermometric control.[10] The modern methods of heating lend themselves so readily to automatic control that the instrument maker is being called upon to design automatic controls for every variety of heat treatment from that of a dental furnace to one capable of taking the largest gun. The application of high temperatures in industry, especially in metallurgical work, has increased the demand for instruments capable of measuring temperature without being placed in the hot zone. The first satisfactory attempt at such a pyrometer was made in 1892 by Le Chatelier. In this instrument, which was a form of photometer, the intensity of the light received from the hot body was adjusted by means of an iris diaphragm (later by means of absorbing-glass wedges) to match that given by a standard lamp. A few years later Holborn and Kurlbaum introduced the disappearing-filament form of instrument which in one form or another is now the most generally used type of optical pyrometer. In this the filament of a small incandescent lamp is interposed between the eye of the observer and the hot body. The current through the lamp is adjusted so that the filament becomes invisible against the incandescent hot body. The Féry pyrometer (1902) consists of a thermo-couple of small mass mounted in the focus of a concave mirror which focuses the total radiation received from the hot body on to the couple. This instrument can be used to measure temperatures throughout a large range. It has also the advantage that it can be readily attached to a recording galvanometer and can thus be made to follow the stages in the heat treatment of materials in a furnace or kiln. Owing to the large amount of comparatively recent theoretical work on radiation problems, the principles

[10] In this connection the work of Wedgwood, the famous potter, should not be forgotten. In 1782 he introduced a method of measuring the contraction of small blocks of china clay of various compositions. The contraction varied with the temperature and a measurement of this gave an idea as to the maximum temperature reached at the time of the withdrawal of the block. This form of pyrometer was in general use in the potteries for over a century.

underlying optical and radiation pyrometers have been exhaustively studied, so that the measurements obtained with these instruments are closely linked to the absolute temperature scale. Thus the upper basic points on the scale of temperatures published by the International Committee on Weights and Measures in 1927 were established by means of optical pyrometers.

The last instrument that I shall deal with is the galvanometer, and that can only be taken as representing the great group of electrical instruments that has come into existence during the past century. At the Faraday Centenary Exhibition, held in London in 1931, an exhibit showing the development of electrical measuring instruments was staged by Mr. R. W. Paul on behalf of the Exhibition Committee. The exhibits showed how cosmopolitan has been the growth of electrical measuring instruments. The galvanometer is no exception to this statement. The name itself was given to a form of electrometer by Bischoff in 1802, and commemorates the discovery by Galvani of the movements of the muscle of a dead frog by electricity. Oersted in 1820 discovered that an electric current would deflect a compass needle, and thus laid the foundation for the many types of moving iron or magnet galvanometers. In 1858 W. Thomson (Lord Kelvin) invented the mirror galvanometer for use with the Atlantic submarine cable ; this instrument made submarine signalling possible. In 1881 the Deprez-d'Arsonval moving-coil galvanometer was invented, and although it had been anticipated by other inventors the credit is due to these two distinguished Frenchmen for the most practical form of galvanometer—the one used in practically every direct-current measurement. The moving-coil galvanometer has been studied theoretically and practically by Ayrton and Mather, Zernicke and Moll, and the result of their work is an instrument of extremely high sensitivity and short period. Paschen, Nichols and Downing and Hill have done much to increase the sensitivity of the moving-magnet galvanometer. (In this connection acknowledgment must be made of the great debt the physicist and the instrument maker owe to that doyen of instrument designers, Sir C. Vernon Boys. The high sensitivity of certain types of galvanometer is very largely due to his invention of the quartz fibre—the ideal material for suspending light bodies.)

The sensitivity of such instruments is now so great that it has become necessary to enquire into the effects of Brownian motion. This has been discussed very fully by Barnes and Silverman,[11] who conclude that there 'is a definite limit set by Brownian motion.' In practice, however, 'mechanical stability and the patience necessary to read long-period instruments are the limiting factors of sensitivity, for an ideal instrument.'

A form of galvanometer which has proved of great service in industry in confirming much theoretical work in connection with alternating currents is the electro-magnetic oscillograph, a galvanometer possessing an extremely short periodic time and fairly high current sensitivity. The moving strip type, in which the element is reduced to the simplest form, consists of a loop of a fine metallic strip stretched in a magnetic field, the air-gap being reduced to a minimum. This instrument was invented by Blondel in 1893, but its development was largely due to Duddell, who, six years later, showed in a series of striking experiments the possibilities of the instrument. Since then

[11] R. Bowling Barnes and S. Silverman, 'Brownian Motion as a Natural Limit to all Measuring Processes,' *Review of Modern Physics*, 6, p. 169 (1934).

its capabilities have been much improved, the latest models having a natural frequency in air of $\frac{1}{17,000}$ second and a sensitivity of 42 mm. at one metre for 0·1 ampere D.C., or with a frequency of $\frac{1}{3000}$ sec. a sensitivity of 580 mm. at one metre for the same current—a sensitivity ten times that possible five years ago. In some of the test rooms of the large switch and cable makers a group of these instruments (sometimes as many as twenty-four elements) is used to record photographically the phenomena set up in the network when a heavy current switch is opened or closed.

The problems connected with telegraphy and wireless have also invoked the aid of the oscillograph. Many of the phenomena to be studied take place in such short intervals of time ($\frac{1}{1,000,000}$ to $\frac{1}{100,000,000}$ sec.) that it is impossible for any form of mechanical instrument to respond. This has brought into general use the cathode-ray oscillograph, a form of which is now so familiar in television sets. The cathode-ray beam is deflected by the current or voltage under investigation, the movements being recorded either by the direct action of the beam on a photographic plate, or by photographing the luminous trace on a fluorescent screen. For the observation of phenomena occurring in extremely short intervals of time the former method is adopted, the writing speed of the spot being approximately one-third the velocity of light.

An address of this nature would be incomplete if no mention were made of the thermionic valve. The story of the development of this device has been told elsewhere [12] and in greater detail than is here possible. Its advent has led not only to the birth of a wide range of new instruments otherwise impracticable, but also to the simplification of many measuring techniques. The thermionic voltmeter was one of the first, if not the first, measuring instrument employing directly a valve and uses to the full its most valuable characteristics as a measuring device. These characteristics may be briefly summed up as rectification, amplification, rapidity of response, and high impedance. Although these are the prime considerations, others, such as high overload capacity, are advantageous. The rectifying action combined with amplification enables alternating currents and voltages as small as 10^{-4} ampere and 10^{-4} volt to be measured, using a robust moving-coil instrument as a direct reading indicator. The low electrical inertia and high input impedance have, when using suitable diode valves, enabled voltages and frequencies up to 100 megacycles to be measured with reasonable accuracy by robust commercial instruments.

The part played by the thermionic valve in the simplification of measuring techniques is now well known to all laboratory workers. As a striking example it is, I think, safe to say that had it not been for the replacement of the mechanical type of electrometer by the electrometer valve or other type of valve combinations, the measurement of pH would not have emerged from the laboratory to spread to almost every industry.

Looking back over forty years' experience in the use of scientific instruments, many of those years being spent in their manufacture and development, I am much impressed with the steadily growing demands for higher accuracy. The development of the high-speed steam engine, and later the motor car, brought about an insistent demand for accurate tools and gauges. This in

[12] E. G. James, G. R. Polgreen and G. W. Warren, 'Instruments incorporating Thermionic Valves, and their Characteristics,' *Proc. I.E.E.*, 85, No. 512 (1939).

its turn necessitated better design in the tools and more accurate measuring instruments. The manufacture of interchangeable components in large quantities has still further increased the demand for accuracy. The introduction of the new alloy steels with the special technique required in their heat treatment created a demand for precision thermometry.

The attitude of the manufacturer towards the scientific instrument has completely altered. He was once sceptical as to its usefulness ; he is rarely so nowadays. In the majority of large works the general control over the instruments is now in the hands of a technically trained man, and that in itself relieves the instrument maker of much anxiety. Another fact that impresses one is the great difference between the methods of manufacture during the same period. Forty or fifty years ago instruments were made in small batches, often by individual workmen. In London they were frequently made for some well-known firm by small chamber men who put the name of that firm upon them. As a result of this procedure the so-called manufacturer very often had not an adequate knowledge of his products : this practice has almost entirely disappeared, to the benefit of customer and maker.

The increased demand for instruments has led to manufacture in the modern sense of the word. An instrument is carefully designed in the drawing office in consultation with the technical expert. The methods by which the instrument is to be made are considered. If the quantities are large, and if a preliminary model has been approved, then the possibility of the use of die castings, hot pressings or plastic mouldings must be considered,[13] and the importance of interchangeability of components emphasised.

In preparing the design of an instrument it must never be forgotten that a good design helps production. It always pays to spend time in the drawing office rather than in the workshop. The application of geometric design, the early exponents of which were Maxwell and Horace Darwin, often reduces the cost of manufacture and makes a better instrument. I think that the experimentalist, in making up his own instrument, should consider whether he can obtain the same result by a simply designed geometric piece of apparatus, rather than the more elaborate design to which he may be attracted.

The demand for instruments is ever growing. As new problems arise, both in science and industry, the requirements become more stringent. The instrument maker constantly receives incentives to progress from the scientific worker to whom he owes not only suggestions but many of his new materials. It is, I suppose, a truism that if knowledge is to progress it is essential that theory and practice advance together. Nowhere is this more true than in the development of scientific instruments.

[13] One of the most striking changes in the technique of instrument design has resulted from the use of plastics. Mouldings are so convenient that in some cases where comparatively few instruments are required annually, the cost of the tool is justified by the time saved in the avoidance of intricate machining operations on insulating materials.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES

COMMUNICATIONS

Dr. V. K. Zworykin.—Electron optics and television.

With the advent of electronic television, freeing both transmitter and receiver from the necessity of rapidly moving machinery, many of the design problems have been shifted from the field of light optics to that of electron optics. The differences in the properties of light and electrons and their refracting fields are in large measure responsible for the superiority of the electronic systems.

Electron optics not only plays an essential rôle in the construction of the most generally used types of pick-up and viewing tubes, represented by the iconoscope and the kinescope, but also in that of the several modifications of the iconoscope, sharing with it the utilisation of the storage principle. These are exemplified by the two-sided iconoscope, the image iconoscope and the low-velocity iconoscope. The latter appears particularly promising, combining a great increase in operating efficiency with elimination of the normal spurious signal. Added improvement in the signal-to-noise ratio of the received picture can be obtained by adapting a secondary emission multiplier for use with the iconoscope.

An important contribution, in turn, of television technique to a branch of electron optics, electron microscopy, is the scanning microscope. This may be regarded as a conventional electronic television system in which both the scanning amplitude and spot size in the pick-up tube are greatly reduced, the mosaic being replaced by the object studied.

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Mr. A. B. Howe.—The development of television outside-broadcasts.

A broadcast television service, such as is provided from the London Television Station at Alexandra Palace, greatly increases its public appeal by the frequent transmission of outside broadcasts. Examples are the Coronation procession, football matches, boxing contests and performances from theatres.

As these events usually take place at considerable distances from the television studios, means have to be found of linking the mobile television control room, used for outside broadcasts and known as the 'scanning van,' with Alexandra Palace. Three methods are at present used for this purpose.

(1) *Radio link.*—This method employs a second van, accompanying the scanning van, and containing an ultra-short wave ratio transmitter. The vision signals from this mobile transmitter are received at a point near Alexandra Palace and re-radiated from the main vision transmitter.

(2) *Cable link.*—This employs a specially constructed, balanced, low capacity, underground cable which runs from a number of points in central London, via Broadcasting House, to Alexandra Palace.

(3) *Combined balanced cable and telephone circuits.*—This provides an increase in the scope of the balanced cable link by extending it by lengths up to two or three miles of underground telephone cable, such as is used for outside broadcasts of sound only.

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Discussion on Artificial radioactivity and its applications.

Dr. J. Lawrence.—Some biological and medical investigations with neutrons and radio-active substances.

Dr. W. B. Lewis.—The production and properties of radio-elements.

Almost every chemical element can now be obtained in one or more radioactive

forms. Many of these have lifetimes which are convenient for experiments. Some may be used as substitutes for radium for therapeutic purposes, many more are useful to the chemist, biologist and metallurgist as marked atoms which may be followed through chemical changes, biological processes and metallurgical operations such as alloying and heat treatment. These radioactive substances are isotopes of the ordinary stable elements and pass through all chemical and other changes just like the normal stable atoms. Their identity is only revealed at the moment of their decay.

By means of the largest cyclotrons some of these radioactive substances are obtainable in quantities comparable with our supplies of radium, others are only obtainable in much smaller amount. Many are prepared through the intermediate production of strong sources of neutrons which may also be provided by high-voltage disintegration apparatus.

A discussion, which may be of value to users, is given of the production and properties of selected examples such as bismuth, iron, bromine, phosphorus, sulphur, sodium, carbon and beryllium. Tables and diagrams are shown which indicate the properties of most of the known radioactive isotopes.

Dr. L. H. Gray and Dr. J. Read.—A neutron generator for biological research.

Homogeneous neutrons of about 2·4 MEV. energy, unaccompanied by γ-radiation, may conveniently be generated in intensities which are adequate for chemical or biological research by means of the D–D reaction. The high voltage generator consists of a 200 kV. transformer, condensers, and continuously-evacuated rectifying valves arranged in the Cockroft circuit to give a few milliamps. at 400 kV. constant potential. A low-voltage arc supplies the deuterium ions which are accelerated down a two-section ion tube to the target, which is at earth potential. The target consists of a copper plate on to which is evaporated a film of 'heavy wax' a little thicker than the range of the deuterons. By a special design of water cooling, giving a very rapid tangential flow of water along the underside of the copper plate, the wax target is maintained well below its melting point. Owing to the intense deuteron bombardment, the wax becomes decomposed and the efficiency of neutron production falls to about 50 per cent. in the course of a month. By proper adjustment of voltages on three electrostatic lenses the ions may be focused at the target to a disc of any desired size. The material to be irradiated may be brought to within 1 cm. of the target. The total neutron output was measured under normal working conditions (300 kV. and 600 μA), with an 'aged' target, by the rhodium method, as $6 . 10^8$ neutrons/sec., or approximately the equivalent of 25 Curies of 'Rn-Be' mixture. The voltage has subsequently been increased to 400 kV., and ion currents of 1 mA. are certainly attainable by this method. At 400 kV. and 1 mA. the output would be about $2 . 10^9$ neutrons/sec.

Discussion on Problems of high-speed flight.

Dr. G. P. Douglas.—Future developments in high-speed flight.

An analysis is given of present attainments, and the possibilities in the immediate and more distant future are considered.

Passage through the air at very high speeds implies very high drag, and the practical limits of high speed flight depend on how far this can be kept down. The efficient production of thrust to overcome the drag at these high speeds presents new problems, and there is a limit above which the conventional airscrew cannot be efficient. For moderately high speeds the engine installation and airscrew must

be carefully designed. A brief review is made of the reliability and adequacy of our present experimental information.

Dr. A. Busemann.—Effect of compressibility on thin slightly cambered aerofoils at sub-sonic speeds.

Flow at sub-sonic velocities in compressible fluids is usually calculated by developing in terms of Mach's number (the ratio of the velocity to that of sound) the variation of the potential function from that appropriate to potential flow, as in the work of Rayleigh and Jansen. The first approximations then hold for any profile and angle of incidence, but only for small values of M. A large number of steps is needed if the result is required for thin profiles and correspondingly high values of M. In this case a step-by-step method of approximation, based on that of Prandtl and Glauert, for thin aerofoils at small angles of incidence is more suitable, and is valid for all values of M below the critical value. In this method the stream function is expanded in terms of a parameter d, which expresses the departure of the form of the aerofoil in thickness, camber and angle of incidence from the basic form at zero incidence. The differential equation permits the calculation in terms of d of the individual coefficients, which are functions of position and of M. The first two terms of the approximation form the Prandtl-Glauert approximation, the first representing undisturbed parallel flow. The third term extends the validity of the approximation to somewhat thicker aerofoils. For several forms, the lift and velocity increment increase more rapidly with M than is shown by the Prandtl-Glauert theory.

Dr. J. W. MacColl.—Some theoretical aspects of high-speed flow.

Supersonic flow past a body is found to differ in a marked manner from flow at speeds below the normal speed of sound. This change in the motion is associated with a change in the form of the governing differential equations. In regions of supersonic flow shock waves are very liable to occur. Although the properties of these waves are well understood, theory is not yet sufficiently well developed for their exact position to be predicted except in a few special problems. The simplest of these is the flow past a wedge at a sufficiently high speed. Under this condition the head resistance of a finite wedge can be calculated exactly. At lower speeds the motion past a wedge is much more complicated, but consideration of the flow near the solid boundary indicates that the general features of the motion can be readily understood. This is mainly due to the conditions at the shoulder of the wedge being constant over a wide range of velocities. Since the flow past a finite cone is similar in many respects to that past a finite wedge, photographs of projectiles in flight can be used to distinguish between the different régimes into which the complete range of velocities can be divided.

Mr. C. N. H. Lock.—Problems of high-speed flight as affected by compressibility.

Extra wastage of power begins to occur on parts of an aeroplane when the local velocity of sound is first exceeded, and is associated with the formation of 'local shock waves,' of which the nature and origin are discussed.

These effects have been investigated in the 1-ft. high-speed wind tunnel at the National Physical Laboratory, in which an electric balance measures the forces on aerofoils of 2-in. chord and other shapes at speeds up to 0·9 of the velocity of sound. The drag is also determined from loss of momentum by exploring the aerofoil wake.

A second high-speed tunnel under construction is of rectangular section and has glass windows in the sides, intended for the photography of shock waves. Aerofoils of 4-in. chord will be 'pressure-plotted' and the flow near the shock waves measured in greater detail.

Among results recently obtained are the distribution of drag losses on two aerofoils similar to the blade roots of variable pitch airscrews, from which the effect of fairing the blade roots has been calculated for aeroplane speeds up to 550 m.p.h.

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Discussion on High-temperature physics.

Prof. Max Born, F.R.S.—A new theory of fusion based on lattice dynamics.

Melting is the breakdown of rigidity of a crystal lattice. This natural definition, which is also used by Brillouin in a paper recently published, can be worked out for cubic lattices by calculating the free energy A as function of temperature T, arbitrary lattice constant a, and 6 strain components x_x, x_y, . . . (Voigt's notation), which can be considered as small. The linear terms of A in x_x, x_y, . . . give the equation of state, $p = f(a, T)$, the quadratic terms the elasticity constants c_{11}, c_{12}, c_{44} also as functions of a and T. The melting curve is the result of eliminating a from $p = f(a, T)$ and $c_{44}(a, T) = 0$. But as there is another stability condition, $c_{11} - c_{12} > 0$, there is the possibility of a transition in a 'gel'-like state before melting proper; this seems to happen in the case of the alkali metals. The calculation can be performed for the cubic crystals of the three Bravais types, assuming central forces. The result is, as expected, a decrease of c_{44} with increasing T, resulting in melting ($c_{44} = 0$). For $p = 0$ one gets Lindemann's formula with a definite constant; for increasing p one obtains a melting curve of the right shape. The method will lead to an improvement of the theory of breaking strength. This problem and the application to metals is worked out by the author's collaborators.

Dr. Ezer Griffiths, F.R.S.—Recent advances in high-temperature technique.

A review of thermal measurements at high temperatures with particular reference to the steel-making industry.

Methods have been devised for the determination of the physical constants of steels up to temperatures of about 1,000° C., also of the thermal conductivities of refractories and insulating materials.

Dr. W. H. Hatfield, F.R.S.—Modern steel metallurgy (illustrated by a film).

The paper deals with the manner in which the weight and quality of the ingot required determines the type of process to be employed, and also emphasises the limitation of process available when extremely large masses of steel are being produced. The essential features are brought out in a colour film illustrating the high frequency and arc electric methods of steel making, and also the acid open-hearth process; the application of the latter to the production of an ingot weighing 180 tons is shown in the film.

The paper then proceeds to consider the mechanism of freezing of the steel, and the implications arising from the effect of differential freezing. The manner in which the design of the mould and of the superimposed feeder head can overcome some of the disabilities arising from the process of freezing is brought out by illustration, and it is shown that with small sizes of ingots, advances in ingot technology have now resulted in the possibility of a very high standard of homogeneity.

Stress is laid on the difficulties in the way of a quantitative control of the physical chemistry governing the relations between the liquid steel and the superimposed liquid slags, and an account is given of recent developments in the way of temperature control and of the determination of the oxygen content of steel.

Particular attention is given to the problem of reducing the amount of non-metallic included matter in the steel to a minimum, and to the effect of such inclusions upon the characteristics of the steel, notably with reference to the finished product.

Mr. W. J. Todd.—High-temperature measurement in steel works.

The characteristics of various instruments available for the determination of liquid steel temperatures at different stages of manufacture are considered.

Since the disappearing filament optical pyrometer has certain practical advantages over other types, its use (including the determination of the temperature of molten steel in the furnace by the spoon sample method) is described, and the various uncertainties arising from practical conditions are indicated.

Reference is made to tests with the colour-temperature optical pyrometer, showing that, while for certain steels the emissivity factor may be corrected to a large extent, errors in the determination of true temperature by this method still exist due to variation of emissivity, especially in the case of highly alloyed steels.

The use of thermocouples on the quick-immersion principle is advocated in conjunction with the disappearing filament optical pyrometer as a means of obtaining the emissivity factor, which may well prove to be an important index of the operating conditions in the steel-making process.

Dr. R. W. Powell.—Measurements of thermal conductivity and electrical resistivity at high temperatures.

Brief descriptions are given of longitudinal and radial heat-flow methods which have been used for determining the thermal conductivities of iron and steels up to 1,000° C. and of determinations to 2,000° C. on carbon and graphite by a method based on observations of the temperature difference between the axis and surface of an electrically heated rod. The experimental results are discussed in relation to existing data for the thermal and electrical conductivities of other conductors, and in general it is shown that departures from the Wiedemann-Franz-Lorenz law tend to diminish at high temperatures.

Mr. J. H. Awbery.—Heat capacity of iron and carbon steels.

The heat capacity of iron and certain steels has been measured by an electrical adiabatic method up to nearly 1,000° C. Pure iron shows a large increase of specific heat associated with the magnetic point just above 750° C. ; the effect, though reaching a maximum at a precisely defined temperature, nevertheless influences the course of the specific heat curve over a very wide range, apparently indeed down to room temperature. Up to the magnetic point, and even beyond it, the shape of the curve is similar to that obtained by earlier experimenters, but at about 900° C. where the lattice changes from body-centred to face-centred, it is found that the specific heat increases steeply before the actual transformation temperature is reached. The latent heat associated with the transformation is found to be 3·9 cals. per gm.

In low carbon steels, the importance of the alpha-gamma transformation is relatively less than in pure iron, but the increase in specific heat at the magnetic point (which, like the alpha-gamma transformation, occurs at a lower temperature than in pure iron) is much more marked. As the carbon content increases, only one peak, at about 720° C., can be identified. In some carbon steels there is a definite latent heat at this point, the steel absorbing heat at the arrest point, without any rise in temperature.

Prof. J. Satterly.—Errors in high-temperature measurement.

The precautions which should be taught to students in connection with the measurement of temperature by resistance thermometers, thermo-elements, pyrometers or mercury thermometers are discussed, together with the means of studying the laws of radiation.

DEPARTMENT OF MATHEMATICS (A*)

Prof. H. W. Turnbull, F.R.S.—Matrix theory in its geometrical aspect.

Geometry and algebra react upon each other to their mutual advantage. Historic development through Descartes, Hamilton and Cayley. Familiar geometrical properties in matrix notation, and generalisations suggested thereby—to higher dimensions, or from real to complex figures. Geometrical linear transformations and reciprocations. Examples where geometry throws light on algebra, or algebra on geometry, taken from continuous or finite groups, orthogonal matrices, hereditary matrices and integral roots of the unit matrix.

* * *

Dr. A. C. Aitken, F.R.S.—Irreducible homœomorphs in the linear group.

Description of the representation of groups by matrices, with examples from simple finite groups. The history of transformations homœomorphic to the linear transformation. The construction of irreducible homœomorphic matrices. Their relation to general matrix theory, to the symmetric group, to Young's substitutional analysis and to combinatory analysis. Applications to the invariant theory of quantics.

* * *

Discussion on The teaching of mechanics.

Prof. E. A. Milne, M.B.E., F.R.S.—Introductory survey.

The study of mechanics and the solution of problems in mechanics are an intrinsic part of the subject of mathematics as taught in British schools and universities ; the subject is associated with such names as those of Routh, Lamb, Loney, Love. It is perhaps a peculiarly British tradition, well worth preserving as a discipline of the first order, comparable with Latin and Euclidean geometry ; many examination candidates, even perhaps theoretical physicists of distinction, can write learnedly on atomic physics, and yet find the greatest difficulty in solving dynamical problems requiring a firm grasp of principle *together with facility in applying it.* The present logical unsatisfactoriness of quantum mechanics in certain aspects may be due to want of interest in the foundations of mechanics amongst its exponents.

Three stages may be discerned in the study of mechanics, namely, (*a*) at school ; (*b*) by undergraduates ; (*c*) by researchers. In (*a*), the Newtonian laws, supplemented by such principles as that of the transmissibility of force, may be taken as experimental dogmas ; in (*b*), they should be derived from ideal experiments, from which the notion of mass is isolated through the adoption of Newton's Third Law as an axiom, following Mach ; in (*c*), the tacit assumptions of the existence of rigid bodies and the ' uniform flow ' of time should be subjected to criticism. Throughout, an attempt should be made to teach mechanics in terms of vectors directly ; the powers of vector analysis in this field have been much developed in recent years by S. Chapman and his followers, and yield beauties and economies of thought undreamed of by the older writers.

Dr. G. P. Tarrant.—Mechanics in the Scottish school.

Tribute is paid to the width of Scottish secondary education and to its wide incidence.

Reasons for the low standard and narrow cultural attainment of science in Scottish schools are discussed and are followed by proposals for remedying such a state of affairs.

The suggestion is made that in the *final* school examination, science subjects, physics, chemistry, and biology, should rank as more than half subjects and should be equivalent to any other full subject such as geography or a language.

Then are considered methods of awakening a livelier interest in mechanics and in giving the subject a wider cultural value through the introduction of examples bearing on practical life, such as the mechanics of athletics and of structural engineering.

Demonstration of illustrative models.

Mr. K. S. Snell.—Mechanics in the secondary school.

There are two stages: (i) the introduction of the subject to all; (ii) a more advanced course for science or mathematical specialists. (i) This should be part of the mathematical course for all. It provides practical application of mathematics, and the pupil needs to draw more on his experience than on experiment, especially in kinematics. The object is to make the important concepts of mechanics, such as acceleration, force, energy, momentum, almost as real to the pupil as things he can touch and see. (ii) The more advanced course is for the specialist. The systematisation of familiar ideas is of basic importance in the growth of a subject and in the education of an adolescent. A boy should be trained to see how a science can be developed mathematically from fundamental assumptions, and how the hypothesis can be verified by an experimental demonstration of the results obtained. The history of dynamics is particularly illuminating in showing the part which mathematics plays in the development of a science.

An attempted course along these lines is briefly described.

Prof. R. Peierls.—Mechanics in the University.

Mechanics, the oldest and best-developed branch of applied mathematics, can be of true instructional value only if in the teaching proper use is made both of general principles and of special examples. The greatest danger of present teaching practice seems to be an exaggerated weight given to special examples without making the student see them as special cases of important general principles which would enable him to deal with different cases which he has not actually met. On the other hand a tendency to introduce too many abstract theorems without sufficient illustration would be equally dangerous.

In many cases, the time taken up by mechanics in the course of applied mathematics is out of proportion to its importance, and insufficient time is left for other branches of applied mathematics, such as elasticity, hydrodynamics, electricity and optics. Mechanics is certainly a much easier subject than the others and therefore deserves more prominence, but, just on account of the extreme simplicity of the principles on which it is based, it does not lend itself to the natural application of some general methods, such as dimensional arguments and asymptotic solutions of problems, which are of great instructional value.

DEPARTMENT OF COSMICAL PHYSICS (A†)

Discussion on Surface temperatures of stars.

Prof. W. M. H. Greaves.—General survey.

Prof. R. W. Ditchburn.—Laboratory experiments on continuous absorption of light.

1. The two experimental methods are described:
   (*a*) Direct measurement of absorption of atomic vapour.
   (*b*) Measurement of number of photo-electrons produced per unit intensity of radiation as a function of frequency.

2. *Results.*

(1) It is shown that where (*a*) and (*b*) overlap, results are in agreement.
(2) Detailed results are given for absorption of Cs vapour. Less detailed for other alkalis. Some mention of H, He, and other rare gases.
(3) Shown that observed absorption for Cs is atomic.
(4) Shape of the Cs absorption curve discussed.
(5) Effect of foreign gases on Cs absorption shown and discussed.

3. *It is concluded:*

(1) That the theory of continuous spectra of atoms is not in a satisfactory state to justify extrapolation to stellar conditions (possible exception of H).
(2) That continuous absorption is not a simple function of number of absorbing atoms present, but is affected by total pressure, temperature and probable state of ionisation of the mass of material. The atomic absorption coefficient is not a constant.

Dr. H. R. Hulme.—General physical theory.

The solution of the problems connected with the outer layers of a star depend to a great extent on a knowledge of the absorption coefficient and its variation with temperature and wave-length. At the temperatures under consideration the absorption arises almost entirely from photo-electric ejection of electrons by the light, which is re-emitted on subsequent recombination. Until recently only neutral atoms were considered as contributing to the general absorption (as distinct from line absorption), and the Quantum Theory enables us to calculate the contribution of the hydrogen atoms in various states of excitation. The absorption of the metallic atoms, of smaller ionisation energy, is not so well known, but is certainly greater than that of the neutral hydrogen, even on the assumption that the metals only constitute a small fraction of the total mass. Both these processes yield absorption coefficients which increase considerably as we go towards the ultra-violet, contrary to the results of observation. The solution of this dilemma may be sought in the absorption of *negative* hydrogen ions, which have an absorption coefficient with a flat maximum in the region of importance.

Dr. D. Chalonge.—Astrophysical observations.

The distribution of intensity, between 4,600 and 3,100 A, in the continuous spectrum of more than 200 stars was investigated by using an objective prism camera fitted with quartz optical parts. The stellar spectra were compared to the continuous molecular spectrum of hydrogen given by a distant discharge tube acting as an artificial star. The spectrum emitted by the discharge tube was carefully compared to the standard lamps used in similar researches by Kienle. The curves obtained by plotting the measured values of log-intensity against $1/\lambda$ consist, for B, A, F types of stars, of two portions of straight lines (4,600 to 3,900 and 3,700 to 3,100 A) separated, in the neighbourhood of 3,700 A, by a jump of intensity.

The colour temperatures T_1, T_2 corresponding respectively to these two parts of the energy curve, the value D of the intensity jump and its wave-length λ_0 were measured.

(1) The values of T_1 obtained for stars of different types are in good agreement with the Göttingen determinations. The mean value of six independent determinations of T_1 for normal AO stars is 17,000°.

(2) The measurement of D and λ_0 for a given star allows a full determination of the spectral type and the absolute magnitude.

Dr. R. v. d. R. Woolley.—Astrophysical theory.

The mathematical theory of the radiative equilibrium of the outer layers of a star (the sun in particular) shows that certain observable properties (the connection

between effective temperature and colour temperature, and the darkening to the limb in various wave-lengths) depend upon the type of equilibrium present, upon the presence of scattering as distinct from absorption, and upon the coefficient of absorption as a function of the wave-length. Little progress has been made with the theory since Milne's classical work (*Phil. Trans. R.S.*, **223**, 201, 1922), but the observational data obtained since then may be reconciled with his conclusion that the absorption is independent of the wave-length, in the sun. It has not been found possible to produce a satisfactory physical basis for this empirical fact. The presence of convection has been suggested by Unsöld and Plaskett, but the theory of this has not been advanced to a definitive conclusion.

Discussion on Solar and terrestrial relationships.

Dr. E. V. Appleton, F.R.S.—General survey : radio effects.

The sun radiates energy to the earth in the form of both waves and particles. But that part of the wave energy which reaches us at ground level as light and heat, and which remains so constant in intensity from day to day, gives no hint of the remarkable variations which take place in the radiations of other types which fail to reach the ground because they are absorbed in their passage through the upper atmosphere. The topmost atmospheric layers constitute, in fact, a solar laboratory in which we are able to study daily the electrical and optical consequences of this absorption. Because of its inaccessibility, events in this laboratory have to be observed mainly by indirect methods such as radio wave sounding, though recently, stratospheric exploration has permitted observations on the ozone layer at 25 km. above ground level to be made *in situ*.

The electrical state of the ionosphere, the atmospheric region which extends from 60 to 70 km. upwards, is the terrestrial index most responsive to abnormal events on the sun. Certain disturbances, known as ionospheric irruptions, are noted to occur there simultaneously with the development of bright solar flares on the sun's surface, while less localised disturbances, known as ionospheric storms, appear to follow a day or two after certain alterations in the appearance of the solar disc. In the former case we presume the abnormal solar emission of electromagnetic radiation, while in the latter case the emission of more slowly moving material particles appears indicated. Bursts of both aetherial and particle radiation from the sun are most frequent and severe when the maximum of the sunspot cycle is reached, while the general emission of ultra-violet light by the sun's disc as a whole has recently been shown to vary directly by 150 to 160 per cent. during the same cycle.

Mr. H. W. Newton.—Solar phenomena and terrestrial magnetism.

The observational evidence of the relationship known to exist between localised solar activity (sunspots in particular) and terrestrial magnetic storms is briefly summarised. Some anomalies and limitations in the relationship are restated. Spectroscopic data suggesting a discrimination of special activity associated with sunspots and with magnetic disturbance are reviewed. Another relationship has recently been demonstrated involving bright eruptions in the sun's chromosphere and simultaneous disturbances in the ionosphere (the speed of solar radiation being a common factor in the observation). For obtaining fresh solar data, the use of the spectrohelioscope devised by the late Dr. G. E. Hale has been chiefly responsible.

Dr. A. D. Thackeray.—Solar phenomena.

Observations of the sun's surface in (*a*) integrated light or (*b*) in specific wave-lengths with the spectroheliograph or spectrohelioscope yield knowledge of conditions existing in the different levels of the solar atmosphere. Cinematography has

recently revealed peculiarities in the motions of prominences. Solar eruptions, found to be commonly associated with radio fade-outs, are visible as intense brightenings in the lines of certain elements, notably hydrogen and ionised calcium; the increase in Hα radiation during an eruption amounts to only a fraction of 1 per cent. of the total Hα radiation from the sun. The primary source of the disturbances affecting the terrestrial ionosphere is not yet known, but many phenomena can be explained on the assumption of a sudden increase in the intensity of unobservable ultra-violet radiation emerging from localised areas on the solar surface.

Prof. L. Vegard.—Auroral phenomena and the physics of the upper atmosphere.

The paper deals with recent observations and interpretations of bands and lines appearing in the auroral spectrum, and gives results regarding its numerous changes of intensity distribution and the physical process in the upper atmosphere which may possibly account for the observed effects.

The wave-length of the strong green and the strong red line have been measured with high precision and found to coincide with OI lines, and a number of weak lines have been measured and interpreted as due to atomic oxygen or nitrogen in the neutral or ionised state. Some ten of these lines coincide with nebular lines resulting from forbidden electronic transitions.

Temperature measurements by means of auroral bands gave an average temperature of $-44°$ C. Measurements from bands corresponding to the upper limit of auroral streamers gave no indications of any increase of temperature with increasing altitude, a result which is in agreement with observations by means of interferometer fringes from the strong atomic lines.

The new results regarding the auroral spectrum, its variations and the temperature of the upper atmosphere derived from it support the theory of the upper atmosphere proposed by the writer in 1923, according to which the extreme upper atmosphere takes the form of a kind of terrestrial corona, produced mainly by the action of a radiation from the sun of the X-ray type.

On this theory we should expect on the day side at least three ionisation maxima in the upper atmosphere.

The high-speed photo-electrons from the solar X-rays is responsible for the upper maximum, which surrounds the whole earth (F_2-layer).

The solar X-rays will form a second maximum lower down where the absorption per unit length of path is a maximum (E-layer).

A third maximum of ionisation is formed by the ultra-violet part of the thermal solar radiation. Within a large wave-length interval in the region between light and X-rays, the absorption coefficient is a minimum and all rays within this interval will produce an ionisation maximum at about the same height, which may be estimated to about 200 km. This maximum should account for the F_1-layer.

A large number of irregularities in the ionospheric layers, which accompany aurora and magnetic disturbances, may also be accounted for, when we take into account the effect produced by the incoming electric rays on the state of the upper atmosphere.

Prof. W. M. H. Greaves.—The 27-day recurrence tendency of magnetic storms.

Prof. F. J. M. Stratton, O.B.E.—General summary.

FILM REACTIONS AS A NEW APPROACH TO BIOLOGY

ADDRESS TO SECTION B.—CHEMISTRY

By Prof. ERIC K. RIDEAL, M.B.E., F.R.S.

PRESIDENT OF THE SECTION.

Towards the end of the last century the biologist and physiologist were agreed that the biological entity was the whole living unit. This century has seen an attack on biological problems by the physical and organic chemist. The study of the living unit has been dropped and in its place we find investigations on specialised processes such as oxidation and reduction or catalytic reactions. It is an unfortunate fact, as the late Sir William Hardy clearly pointed out, that in this method of approach the mechanism of the co-ordination or the integration of the activities of an assemblage of cells must remain insoluble. It is this very point which I think deserves some consideration. We know for example that at death the catalysts escape from control since the molecular structure of the moving parts gets disorganised. Again, Loeb showed that unfertilised sea urchin's eggs could be made to develop by immersion in salt solutions of sufficient concentration. In development a whole series of complicated chemical reactions are set in operation and it is clear that in the quiescent unfertilised egg all the chemical ingredients for the reactions are present but await some change in organisation before reaction sets in. We must conclude that the mechanism of integration is at any rate dependent on a pre-existing organisation of at least the major operative portions of the assemblage of cells. This raises a number of important problems such as, what types of organisation are to be found in living material ; how far control over chemical reactions can be effected by modification of the type or extent of such organisation, and finally how far different types of organisation can modify such important factors as the chemical or physical state of a material or chemical equilibria in reacting systems, and lastly what new properties or reactions make their appearance as a direct result of organisation.

Whilst it has been frequently stated that one of the chief characteristics of living matter is that it contains a relatively large proportion of matter in what we designate the colloidal state, a closer analysis indicates that in fact the colloidal properties of living matter are due to the fact that an exceptionally large fraction both of material and of energy is present in films, membranes, fibres, fine capillaries and the like. It thus seems pertinent to inquire a little into the properties of surfaces of separation between bulk phases or of matter in the boundary state. These surfaces of separation can be considered as a

new phase—the interphase—and for our discussion we must examine this phase and find in what respect it differs from the enclosing bulk phases.

Whilst we must pay attention to the static properties such as composition, form and orientation we must not forget that it is the dynamic properties of ingress and egress, of flow and chemical action in and with the two-dimensional contents of the phase that we are particularly interested in, but any integrating features of the former are of great importance if it can be shown that they produce effects in the dynamics of the system which are not to be found in non-structural liquid or vaporous phases.

We already know that the composition of the interphase differs from that of either of the bulk phases in contact with it and the general principles governing relationship between its composition and its three-dimensional partners were clearly enumerated by Willard Gibbs and Sir J. J. Thomson. Equally important are the considerations of Sir William Hardy and Irving Langmuir, who showed that in many cases when dealing with an interphase we were actually examining a monolayer—a hypothesis suggested by Lord Rayleigh. Finally we know the molecules contained in the monolayer are orientated with respect to one another and to the plane of the interphase. I need not enlarge at this point on the structure and different physical states as well as the effects of variation of the external variables on the equilibria of the phases of monolayers of simple molecules such as derivatives of both paraffinic and cyclic hydrocarbons, since these have been exhaustively examined during the last twenty years, but monolayers both of macromolecules as well as those composed of binary and components of a higher order possess a number of interesting and somewhat unexpected properties.

We find, for example, that macromolecules such as the methylated or acetylated starches and celluloses or the native proteins can be spread as monolayers. The chains are extended at the interface and in general the non-polar side chains penetrate into one (the non-polar) and the polar side chains into the other (the aqueous) phase. This separation of the side chains by the solvent action of the homogeneous phases can only be effected by suitable partial rotation along the chain involving the usual cis-trans motion. Thus no single protein chain can acquire along its entire length either the α or β keratin configuration unless the side chains alternate in polarity in suitable fashion. Monolayers of both the proteins and of the derivatives of starches and celluloses when suitably compressed acquire rigidity and interesting elastic properties; we are forming in fact a two-dimensional gel, the prototype of a membrane. We shall return to some of the reactions which are observed with such monolayers, but may observe in passing that these macromolecules in a monolayer are in part crossing one another by the accident of distribution, in part associate with one another through three separate factors: (*a*) the non-polar side chains forming a hydrophobic surface to a triplex sheet; (*b*) association through the —CO—NH linkages in the chains; (*c*) association between some of the polar heads in the substrate. It appears that at extremely great surface dilutions of many proteins actual molecular separation occurs and we are thus presented with a simple method of determining the molecular weight from the relation FA = RT of these complex bodies.

We have referred to the fact that molecules in a monolayer are orientated relative to one another and to the substrate and that this orientation can be

altered by extension or compression. If the molecules in the monolayer undergo reaction with a reactant dissolved in the substrate the rate of reaction may be modified by the change in molecular orientation of the former. This is equivalent to a control of the steric factor and determining the path of approach of a reacting molecule or ion to the reactive portion of the other reactant. In this way both the reaction velocity and the height of the energy barrier or apparent energy of activation may be altered.

In the following tables and graph are given three different examples of such a variation in reaction effected by change in compression of a monolayer.

Oxidation of Erucic and Brassidic acids by 0·005 *per cent.* $KMnO_4$ *and* N/100 H_2SO_4.

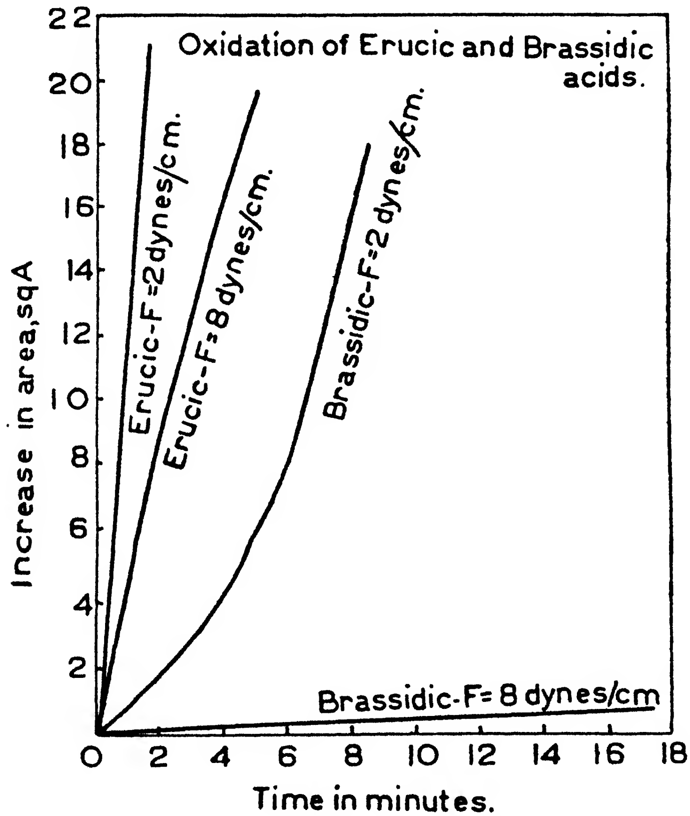

FIG. 1.

Hydrolysis of Trilaurin on N/5 *NaOH.* $T = 20°$.

F dynes/cm.	E cals./gm. mol.
5·4	10,000
10·8	13,200
16·2	16,100

Attack on Lecithin monolayers by 0·001 *per cent. black tiger snake venom at* 20° *and* pH 7·2.

No. of lecithin molecules per sq. cm. $\times 10^{-14}$.	Half life in minutes.
1·04	0·5
1·27	4
1·57	32
2·11	90

It is interesting to observe that these film reactions can be carried out with minute concentrations of strongly adsorbed reactants. Thus in the case of the attack of lecithin by snake venom to form lysolecithin a half life of about one hour is obtained with a concentration of venom as low as $2\cdot5 \times 10^{-6}$ per cent. When cobra venom is examined by this method it is found that only in extreme dilutions does any reaction occur. This inhibition at higher concentrations is due to proteins present in the cobra venom which are absorbed in preference to the enzyme by the lecithin monolayer. Egg albumin, although not so effective when added to black tiger venom, will produce a similar result. In addition to lecithinase present in snake venoms, other enzymes have been studied and amongst them crystalline trypsin and crystalline pepsin which rapidly digest monolayers of caseinogen, the former at pH 8 and the latter at pH 2. When the purified and crystalline enzyme preparations are employed, these enzyme actions on the protein monolayers behave exactly as in bulk phase, although the protein has undergone a process akin to denaturation. With unpurified proteolytic ferments, on the other hand, fatty acid protein complexes are invariably present which give rise to other phenomena.

In the reactions which we have discussed the chemical processes involved do not differ from those which would occur in similar systems in the disorganised state and the only effects of molecular organisation into orientated monolayers are noted in the alterations produced in accessibility of the groups as revealed by the rapidity of the reactions and in the apparent energies of activation.

A further consequence of molecular orientation at interphases is found in those cases where radiation incident on the surface produces photochemical action after absorption of quanta by chromophoric groups in the monolayer. If, as is the case in ring compounds, the extinction coefficients are different along the three molecular or group axes, the photochemical reaction rate can be varied by alteration of the orientation by compression. Thus the rate of photochemical hydrolytic fission followed by oxidation in protein monolayers at those points along the chain where the chromophoric groups are situate can be varied within wide limits by simple expansion or contraction.

There are several processes in which an alteration in the properties of an interphase bring about a number of varied biological processes of great importance, I may mention the phenomena of lysis, agglutination, sensitisation and the lethal activities of certain substances on various types of cells and micro-organisms. It is true that we are not yet certain in any one case as to the exact composition, structure or thickness of the cell membrane, but we are certain that the surface structure must be organised in the sense that forces of molecular orientation must be operative in the membrane. Whilst, as we have seen, a monolayer membrane of a protein may be destroyed by suitable

enzymes, yet the phenomena which I am now referring to do not appear to be the result of chemical action in the usual sense of the word. The reactions themselves do not appear to possess large temperature coefficients indicative of sensible energies of activation, although it must be admitted this fact is frequently obscured by other processes operative at the same time. We may mention in passing the thermal denaturation of proteins is a reaction in which the apparent and true energies of activation are markedly different, a fact emphasised by the investigations of Steinhardt and La Mer. A second criterion is to be found in the fact that these processes are nearly all catastrophic in character, i.e. the process under investigation being recorded as a hit or miss. As far as quantitative results are possible in such systems it appears that a definite quantity of reactant related naturally to the extent of all surface is required to bring about the reaction, and further that this quantity is removed from the environment on to or into the cell wall. One further point of interest is that the relation between the quantity on or in the cell wall and the concentration in the environment can be expressed in terms of an adsorption isotherm. Not too much stress may be laid on this last point, because the adsorption isotherm may equally well be replaced for existing experimental data by a partition function between two phases or by the mass law operative between easily dissociable salts.

Whilst the extent of mutual miscibility of two liquid phases is usually interpreted in terms of the relative internal pressures of the two liquids, we note from the molecular point of view especially in the case of the large complex and the biologically important material, that we are really concerned with specific molecular interactions which may be identified as being due to those forces operative between the non-polar and the polar portions of the molecules respectively. In two component monolayers the two molecular species are adlineated in respect to one another and we should thus anticipate that it might be possible to form relatively stable two-component complexes which in three dimensions would only be detectable in terms of mutual solubility and when a mutual solvent was present as a third component might not be observable at all. These conclusions are indeed fully borne out by investigations on two component monolayers. It is found for example, that strong complexes are formed in mixed monolayers of a variety of substances such as saponin with cholesterol or digitonin or cetyl amine or sulphate with cholesterol.

Examination of a great variety of these systems has demonstrated that the free energy of formation of the complex is constitutive in the sense that its magnitude is dependent on the extent of interaction between the polar reactive groups and also that of the Van der Waals interaction between the non-polar portions of the reacting species. The difference in properties of mixed films containing cholesterol on the one hand and those containing, for example, epi-cholesterol is most marked, but when models are made of the two molecular systems, it becomes quite evident that the ease of adlineation of the hydrophobic portions of the molecule and the relative orientation of the polar group with respect to the axis of the molecule are the determining factors. The free energy changes involved in formation of these two-dimensional complexes is of the order of some 10,000 Cals. per gm. mol. Complexes containing the constituents in ratios other than one to one can be prepared ; thus cetyl alcohol and cetyl sulphate can form both a 1 : 1 and a somewhat unstable complex

in the ratio of 1 : 3, whereas elaidyl alcohol produces an unstable 1 : 2 but no 1 : 3 complex. It is probable that with a more extended investigation of these interesting systems the basis for the most elementary form, i.e. a two-dimensional crystallography of the type envisaged by Patterson may be laid down.

I might mention in passing that the effects of cis-transisomerism on the free energies of the complexes are very characteristic and fully confirm the hypothesis we have advanced as to the importance of molecular adlineation ; thus saturated aliphatic hydrocarbon chains with different reacting polar groups will form stable systems, likewise trans-olefinic chains can penetrate and pack both with one another and with saturated chains, but the cis form is not capable of such adlineation. From the biological point of view I think that the most interesting property of these systems lies in the mechanism of their formation, for on injection of one of the reactants beneath a monolayer of the other it is found that penetration of the latter by the former will take place to form the complex monolayer. This penetration, if carried out at constant area, naturally involves a rise in the two-dimensional pressure, or if at constant pressure a rise in area is involved. We have indeed examined the formation of complexes under both these conditions, and the changes involved are frequently remarkable, thus the injection of a few mgm. of saponin under a film of cholesterol compressed to a pressure of 10 dynes/cm. will cause an increase of pressure of over 50 dynes/cm. Whilst a film of cetyl alcohol at 20 A^2 per molecule expands to no less than 78 A^2, even when the pressure is maintained at 23 dynes/cm. on the injection of only 1 mgm. in 300 cc. of cetyl sulphate.

If sodium cetyl sulphate be injected beneath a monolayer of cholesterol this substance will penetrate to form, as we have seen, a complex. By suitable adjustment of the pressure this complex can be maintained at the definite composition of one to one, excess of the sodium salt being ejected as the pressure is raised. It is found that the pressure on the film has to be raised as the concentration of sodium salt in the substrate is raised ; some of the values obtained are given below.

Conc. Sodium Cetyl Sulphate gms./cc. $\times 10^{-7}$.	Equilibrium pressure in dynes/cm. for the 1·1 complex formation.
1·0	17
2·0	32
3·0	38
4·0	45
5·0	47
6·0	48

We conclude that there must be a more or less complete layer of the sodium sulphate adsorbed beneath the surface of the complex. We are thus led to the view that in many oil in water emulsions as well as in the micellar aggregates found in soap solutions the gegen ion atmosphere around the emulsion particle or micelle must contain a number of molecules of the emulsifying soap, a somewhat novel conclusion as to their structure. Further, that emulsions formed from such complexes should be remarkably stable with a low interfacial

energy. In some cases a small alteration in the *p*H of the substrate may affect the ease of penetration of a reactant to a marked extent. In the diagram is shown the effect of such a variation on the rate and extent of penetration of bilirubin into cholesterol as a function of the *p*H. It is possible to examine the reactivity of various substances in respect to penetration of monolayers.

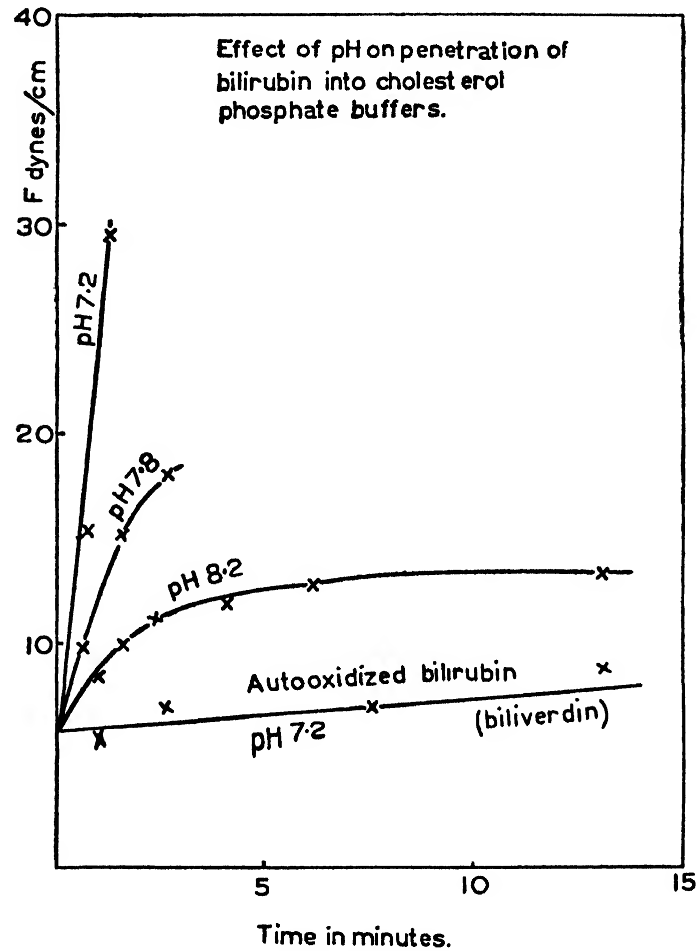

FIG. 2.

I have referred to the penetration of monolayers of cholesterol and we note that some substances such as digitonin or cetyl sulphate or amine possess this property to a remarkable extent. Of the other important cell wall constituents we include phospholipins and the proteins. Little information as yet is available on phospholipins, but our knowledge of the reactions of this type in the case of the proteins, especially the alcohol soluble and thus readily dispersible protein gliadin, has been greatly extended in recent years.

The stability of the protein monolayer is, as we have seen, due partly to their mutual association ; if these are broken down by stronger associating

reactants we might anticipate a dispersion of the monolayer resulting in a solution of the protein in the form of a protein-reactant complex. This phenomenon is readily observed on injection of even minute quantities of such substances as sodium oleate, cetyl sulphate, or psychosin beneath a protein monolayer.

Other substances may react by penetration into the protein layer but not effect dispersion. By spreading monolayers with various head groups and examining the reactions caused on injection it is possible to identify the reacting group in the protein monolayer. A characteristic group of protein complexes formed in monolayers are the lipo proteins, thus gliadin forms a remarkable complex with cholesterol in the ratio 4 : 1 by weight. Here the cholesterol is anchored to specific groups in the gliadin, in particular the amino and carboxylic groups. At high pressures (20 dynes) the cholesterol is forced up above the protein monolayer and the surface becomes one essentially of cholesterol. Nevertheless the cholesterol is still anchored to specific portions of the protein, for on release of the pressure the lipo-protein film is re-formed. This extrusion and re-forming process can be repeated several times before the complex structure breaks down. It is interesting to note that saponin which penetrates cholesterol with extreme ease, but proteins only slightly, will penetrate these lipo-protein films except at those pressures where the cholesterol is separated from the substrate by the protein monolayer to which the cholesterol is anchored.

It thus appears not unlikely that the materials such as cytoplasm, and especially in the more stratified chloroplasts, must be regarded as a protein gel framework to which is attached the enzymes, the phosphatides and lipoids and the means of attachment is as we have seen due to the interaction both of the non-polar as well as of the polar portions of the molecules concerned. Another important conclusion to be drawn from monolayer experiments is that these penetrative reactions involve not only a new head group interaction, but in many cases also the breaking of such a head group interaction already existing in the monolayer prior to penetration. Several biological analogies may be mentioned—thus since lysis of blood cells can be brought about both by protein and cholesterol penetrants we must conclude that it has lipo-protein surface. Several micro organisms can be sensitised for lysis by cholesterol penetrants by a prior treatment with cholesterol. Again, cilia of mytilus appear to be mainly lipoidal, those of paramœcia chiefly protein, as judged by the criterion of penetration.

The carrier action of desoxycholic acid on fatty acids can readily be demonstrated in monolayers, as desoxycholic acid does not interact with other lipoids nor to any great extent with proteins. We find also that the hæmolytic activity of a long chain alcohol is negligibly small owing to the fact that it is practically insoluble in water, but it readily forms a soluble complex with a long chain sulphate and can be transported to the cell wall in this form. There both the sulphate and the alcohol can penetrate separately, the former acting both on the protein and on the lipoid, the latter only on the protein, and produce lysis.

Yet another reaction of this type has been described by Peters and Wakelin who found that the complex ovoverdin containing protein and astacin could be split to form a lipo-protein containing soap by the addition of small amounts of saturated long chain fatty acids setting free the astacin. On the addition

of calcium ions the process is reversed. They likewise draw attention to the fact that it seems probable that the co-enzyme in an oxidase system may be separated from the enzyme by the formation of such a lipo-protein complex.

Somewhat more complex in behaviour are the blood coagulants heparin and the synthetic sulphate celluloses. It is found that their biological activities run parallel to the ease with which they penetrate films of cholesterol. It is not unlikely that they operate by breaking down a cholesterol cephalin complex setting the latter free.

We have referred to the fact that for the penetration of a monolayer by a substance injected into the substrate primary interaction between the reactive head groups occurs, followed by solution, i.e. penetration and adlineation, of the tail. In the case of reactants containing two or more reactive head groups it is found that these can associate with head groups in the monolayer and thus form a series of links. Here another important factor is found operative. If the injected bipolar molecule possess a hydrophobic portion of such a structure that it can pack or adlineate with its neighbours beneath the monolayer, the resultant composite film is remarkably stable. Thus the long chain dibasic acids are adsorbed on to, but do not penetrate monolayers of amines, whilst the diamidines are adsorbed by, but do not penetrate monolayers of cholesterol. Substances containing the phenolic group are of particular interest in this respect as they include a number of biologically important substances. They react with amine groups quite readily and to a less extent with the imido group in a polypeptide chain. Gallic and tannic acids react with great ease with monolayers both of amines and with proteins. It is interesting to note that the reactivity of tannic acid with the spaced amine groups of the protein is high and that subsequent injection of fatty acids beneath such treated monolayers in the dispersion of the galloylamine or galloyl-protein complex film, but not in the tanned one—an indication of the effectiveness of the interlinkage produced in the non-dispersible network by the multiple point contact of the large tannic acid molecules.

The extremely reactive œstrogenic compounds of Dodds and Lawson of which the *pp′* dihydroxy diphenyl hexadiene and stilbene derivatives form a definite series in which the ratio of hydrophobic to hydrophilic portion can be varied, present an interesting series, the results of injection of which under a protein monolayer are shown in the attached curve.

It will be noted that reaction sets in rapidly but equilibrium is only finally attained after some 15 to 20 minutes, and that there is a parallelism between the œstrogenic activity and the protein adsorption except in the first and the last members, points we shall refer to later.

In apparent conformity with Traube's view, there is a marked increase in adsorption with increase in the number of CH_2 groups in the molecule, and this adsorption is cut down by the insertion of polar groups. This effect is clearly exemplified in comparing the diethyl stilbene or dibenzyl compounds with the corresponding pinacols. If, however, reactive polar groups, e.g. the phenolic hydroxyl, had been inserted instead of the primary alcoholic groups in the pinacols, a marked increase rather than a decrease in adsorption would have been observed, for the following compounds react in order of increasing adsorption on both amine and protein monolayers—cresol, gallic acid, digallic acid, purpurogallin and tannic acid. This order is, however, reversed to give

a normal Traube series when these substances are injected under a relatively non-reactive monolayer such as a long chain acid.

A wide variety of substances have been examined from this point of view, namely their extent of interaction with protein monolayers, and it has been found that there is a direct parallelism between their extent of interaction and their lethal action on paramœcia. Another significant biological similarity

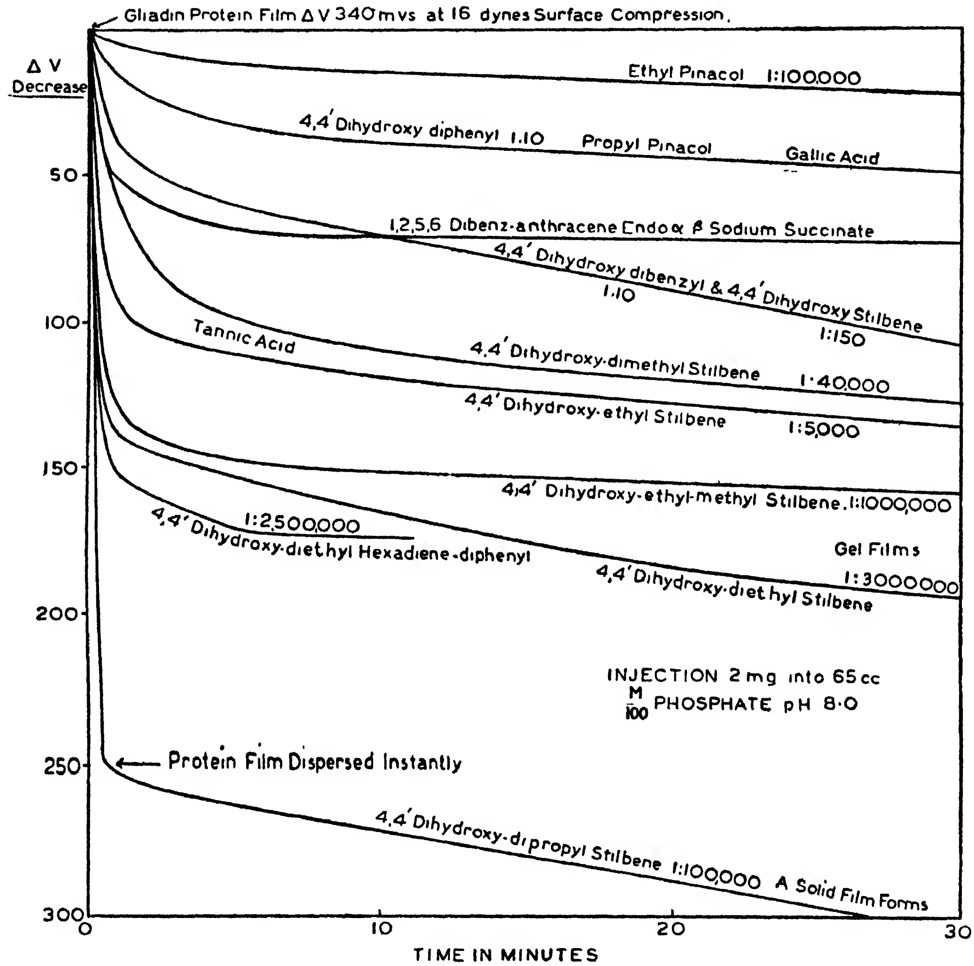

FIG. 3.

has been noted when we measure the extent of penetration of a series of substances containing identical hydrophobic ' tails,' e.g. a C_{12} chain but with different head groups, into a monolayer of a typical lipoid such as cholesterol. In all cases the extent of interaction as measured by the increase in surface pressure caused by the injection of 0·33 mgm./100 cc. under a film of cholesterol originally extended to 40 A^2 per molecule is found to be closely parallel to the hæmolytic activities and lethal activities on paramœcia of these substances.

These latter can be placed in order both of monolayer penetration and biological activity as follows :—

$$RNH_3^+ > RSO_4' > RSO_3' > RCOO' > R\overset{+}{N}(CH_3)_3 > RNH(\overset{+}{C}H_3)_2 >$$
Bile acids.

We may conclude that the most reactive group in the protein macromolecule is the amino group, since the —NH—CO— group is poorly reactive, a point of some interest when we examine the reactions of lecithin and of cephalin. This order of head group reactivity receives confirmation when penetration into monolayers containing these head groups is examined, i.e. on inverting the system. When we compare the reactivities of a series of long chain compounds with identical head groups it is found that biological activity and film penetration commences with C_9 when attached to a very reactive head group, with C_{12} when attached to a poorly reactive group, and reaches a maximum value at *ca.* C_{18}. It is interesting to note that it is not necessary for all the carbon atoms to be in the form of a chain but may be enclosed in ring systems ; thus activity commences with diphenyl derivatives and increases with addition of carbon atoms to an optimum as in the bile acids, stearic acid, diethyl stilbene and benzpyrene. By examining the reactivity of substances containing two reactive groups at various spacings underneath protein monolayers, it is possible to obtain some idea as to the statistical distribution of the reactive groups in the monolayer. It would appear that some 12·5 A is the mean distribution of the amine groups beneath a gliadin film. In the native protein such spacings are naturally different and thus reactions involving two-point contact will not take place in bulk phase unless the spacing is unaffected by two-dimensional unrolling of the protein.

We have referred to the modification which must be introduced into either the Overton Meyer or Traube concepts of biological activity, i.e. lipoid solubility or capillary activity necessitated by the concept of specific head group interaction. We see that a definite limit is also set to the hydrophobic portion of the molecule, not only on account of the decreasing solubility in the aqueous phase causing difficulty in transport and on account of the ease of adlineation or packing having an optimum of C_{18} for association with sterols or fats, but also because a new phenomenon, as exemplified in the figure, sets in with long chains, viz. dispersion of the monolayer, most marked in the case of 4 4′ dihydroxy dipropyl stilbene. It is possible that this phenomenon of film collapse and dispersion may be a generally important factor in setting the upper limit to the chain length or more generally the capillary activity of homogeneous series of biologically important substances, e.g. anæsthetics. This dispersion of protein films may have biological counterparts in adsorption on specific portions of the cell surface similar to the hæmolytic activity of long chain compounds such as oleic acid which readily disperses protein films. Another interesting parallelism has been observed in the surface reactivities and œstrogenic powers of two isomeric compounds (*pp′* dihydroxy diethyl dibenzyl), one being markedly differentiated from the other in both protein adsorption and in œstrogenic activity. Here models indicate that the trans arranged rings can pack laterally with one another in sheet form much more readily and with a greater degree of adlineation than the cis

structure, imparting stability to the adsorption complex formed with the former substance.

In advancing these somewhat novel principles based upon the hypothesis of a parallelism of film reactions and biological activity, it is desirable to point out exceptions. It is found, for example, that 4 4′ dihydroxy diethyl pinacol is a much more effective œstrogenic agent than either its paramœcicidal activity or adsorption on protein monolayers would suggest. The view might be advanced that on certain living tissues it can be partly converted by enzymitic dehydration to the extremely active 4 4′ dihydroxy diphenyl hexadiene. Another interesting exception is to be found in desoxycholic acid which is the only hæmolytic agent in the bile acid (*ca.* 1 : 550) series and is likewise lethal on paramœcia. It is as we have seen unreactive to films of protein, cholesterol and glycerides, and in fact a specific interaction with fatty acids is involved.

This method of attack permits us to investigate the nature of the coatings of cells or unicellular animals and plants by examining the effects of lipoid or protein penetrating substances on them.

Thus both red cells and paramœcia are affected by both lipoid and protein monolayer penetrating (cytolysing) or adsorbing (agglutinating) agents and we deduce that their surface structures must contain lipoproteins or consist of a lipoid protein mosaic ; whereas certain other unicellular animals frequently found associated with paramœcia and in addition the cilia of mytilus are not affected by protein dispersants but are readily influenced by lipoid penetrating agents, and their coatings in consequence must be chiefly lipoidal in nature.

Examination of the carcinogenic hydrocarbons by the monolayer technique reveals the interesting fact that whilst they themselves are unreactive they are readily converted into extremely reactive water-soluble photo-oxides. These substances are not only reactive to protein monolayers like the water-soluble dibenzanthracene endosuccinnate, but also are paramœcicidal, the parallelism between the biological activity and monolayer reaction being maintained.

Many attempts have been made to construct model systems to yield potential differences analogous to the bioelectric potentials observed in tissues. The work of Beutner, Bauer, Cremer and others suggests that potential differences of magnitude corresponding to those found in living systems can be obtained by interposing suitable oil phases between electrolytes of different composition, and the fact that the penetration of large molecules into living cells frequently follows their lipoid solubility has given support to the theory that the seat of the bioelectric potential lies in the lipoid-like cell wall. The order of thickness of such cell walls cannot exceed a few molecular layers and we must take this fact into consideration. We have noted that at the lipoid-water interface there will exist an orientated layer of dipoles, and on placing a monolayer at the interface, the original array of solvent dipoles will be replaced by one consisting of the material of the monolayer. If an electrolyte be brought to equilibrium in both the homogeneous phases, it is clear that opposite the monolayer in both the aqueous phase and in the lipoid phase adsorption and electrokinetic potentials[1] will be built up of such magnitudes that the total potential fall

[1] Whether adsorption or electrokinetic potentials will be built up in any specific case will depend on whether short or long range forces are involved, i.e. on the magnitude and spacing of the dipoles. If the dipole system occurs across a relatively thick multilayer the potentials will be purely electrokinetic.

across the interface, which may be written $\xi_{oil} + \Delta V + \xi_{water}$, must be zero. If the lipoid phase be replaced by air no diffuse double layer can be built up, since the gaseous ions produced by the usual radioactive source are continually drawn into the liquid phase ; there is in consequence a permanent potential fall equal to $\Delta V + \xi_{water}$, which is the one customarily measured.

It is evident that a bioelectric potential difference may be caused by a sudden alteration in ΔV, for the compensating potential differences ξ_{oil} and ξ_{water} must take time to readjust themselves by diffusion to the new equilibrium values. Since in general the electrolyte concentration in the aqueous phase is high, it seems probable that ξ_{water} will adjust itself to the new value acquired by ΔV as rapidly as ΔV can be caused to change either by mechanical, electrical or chemical means. Thus surges in potential difference across the interface due to a periodic alteration in ΔV may be caused by the slow readjustment of ξ_{oil}, for it is in this phase that the ionic concentration is low.

Another source of biological potentials is to be found in the case where the chemical potential of the electrolyte is not the same in the two phases, bringing into existence a diffusion potential across the interface from source to sink. It is clear that a monolayer can only affect the diffusion potential provided that its permeability to the ions is not only comparable to that of the homogeneous phases on each side, but that it also is not equally permeable to both ions. Experiments have shown that monolayers and even built-up multilayers of considerable thickness of proteins are surprisingly permeable to ions and we must presume that the bioelectric potentials do not involve only a protein membrane between the ionic source and sink. It thus appears that there is some justification for the assumption that it must be a lipoid or a lipo-protein membrane.

It has been the purpose of this address to re-emphasise the importance of the fundamental concepts introduced by Sir W. Hardy and Dr. I. Langmuir as to the structure of matter in the boundary state. I have attempted to show that there is implicitly contained in the concept of molecular orientation a whole series of properties and events for which there are no analogies in homogeneous bulk phase systems. We note that many of the modes and types of the reactions which can be effected in monolayers, and which can be defined with precision and their mechanism established with a considerable degree of assurance, are unique for such interphases, but are again observed in living and organised material. It is with this object of ultimate correlation with biological behaviour that we have taken up the detailed study of interfacial reactions at Cambridge, and I should like to express my deep indebtedness to my colleague, Dr. J. Schulman, who has been associated with me in this object.

Many ' vitalistic ' models have been proposed in the past, and whilst it might be correct, although unscientific, to suggest that the ultimate level of integration in living matter is incapable of examination and definition, yet I believe that one is justified in asserting that at least one of the important levels to which due attention must be given for a proper understanding of biological activities is that of the ordered interface.

SECTION B.—CHEMISTRY

COMMUNICATIONS

Joint Discussion with Section I (Physiology) on Tissue respiration.

Prof. R. A. Peters, F.R.S.—Introduction.

Tissue respiration is an old problem in an extremely modern dress. The bounds of the subject are defined by the entry of oxygen into the cell and the subsequent escape of carbon dioxide and water, and comprise the changes limited by these two events. It is a revolution to realise that the oxygen which leaves the cell as carbon dioxide is not that which enters as gas. The final combustion with its consequent liberation of energy is due to a succession of oxidations by well-defined and highly specific stages, each of which has its own specific catalysts. In most cases the gradual oxidation of a substance (such as a sugar) involves the successive removal in steps of two hydrogen atoms. Part of the catalytic system involved consists of enzymes of protein nature (the true catalysts), and part of hydrogen atom carriers. Several of the latter have been defined by synthesis (e.g. riboflavin). In addition some are components of the vitamin B complex, and so bring this subject into relation with important aspects of qualitative nutrition. The reduction of incoming oxygen is effected by porphyrin-containing systems (in the main) linked with the hydrogen atom carriers ; carbon dioxide is generally removed by decarboxylation of α-keto acids. The necessity for all this complication is determined by the limits of *p*H and temperature compatible with life.

The discussion follows the logical plan of description of the isolated components, discussion of partial integrations and finally of the cell itself with its surface factors organised.

Dr. Malcolm Dixon.—Catalysis in tissue respiration.

Dr. H. Theorell.—Recent research on flavoproteins.

The past year has brought with it a new and surprising development in our knowledge of the yellow ferments. Warburg-Christian's ' old ' ferment of 1932, ' flavin-mono-nucleotide proteid ' was always very difficult to fit into any physiological context that might explain the vital importance of B_2-vitamin. This difficulty has now been overcome since the discovery of a number of new yellow enzymes. The prosthetic group in these is not lacto-flavin phosphoric acid, but lacto-flavin phosphoric acid-adenylic acid. This latter in combination with various protein components gives rise to the following enzymes ; we know for the present seven different flavin enzymes :

1. The ' old ' yellow ferment (*Warburg* and *Christian* ; *Theorell*) = alloxazine proteid $_{O_2,\ \text{dihydro-pyridine}}$.

2. An alloxazine-adenine-proteid $_{O_2,\ \text{dihydro-pyridine}}$ produced by Warburg and Christian, whose prosthetic group is alloxazine-adenine-dinucleotide and whose protein component is = the old ferment.

3. Krebs' d-amino-acid-oxidase = alloxazine-adenine-proteid $_{O_2,\ \text{amino-acids}}$ (*Das*, *Straub*, *Warburg-Christian*).

4. *Haas*' alloxazine-adenine-proteid $_{\text{(methylene-blue), dihydro-pyridine}}$.

5. *Ball's* alloxazine-adenine ? -proteid $_{O_2,\ \text{xanthin}}$.

6. *Corran and Green's* alloxazine-adenine-proteid $_{\text{(cytochrome c, dihydro-pyridine)}}$.

7. *Straub's* alloxazine-adenine-proteid, cytochrome, dihydro-pyridine = co-enzyme factor, diaphorase.

The properties of the various enzymes are discussed.

Prof. D. Keilin, F.R.S.—Cytochrome and similar compounds.

Dr. F. Dickens.—Interpretation of intermediary metabolism from measurement of tissue respiration.

Information on intermediary oxidation in tissue metabolism is still fragmentary compared with knowledge of fermentation reactions. The methods of study make use of isolated enzyme systems, and also of tissue-respiration measurements. The former require complete destruction of the tissue, while this is avoided as completely as possible in the latter. *In vivo* measurement being difficult, most work has been done using isolated tissues. The tissue-slice method of Warburg has proved the most fruitful compromise between the intact and macerated state. Minced tissue (' Brei ') with greater or less destruction of cell-boundaries is particularly valuable for experiments with substances to which the intact cells are impermeable. Some special cases are discussed illustrating the oxidation of various metabolites and intermediates.

For various reasons it does not follow that the addition of a normal foodstuff or intermediate will necessarily increase tissue respiration. Further information may be given by measurement of respiratory quotient. On the other hand, certain activators are able to increase respiration without being normal intermediates. However, by using suitable conditions in which the concentration of certain normal intermediates is reduced so as to become the ' limiting factor,' the importance of these may be demonstrated.

The use of poisons and inhibitors supplies further evidence. The respiration has to be considered in relation to synthetic mechanisms which require energy, such as protein synthesis. Such reactions appear to demand the intact cell structure. The same applies to the Pasteur effect, by which the respiration suppresses the fermentative breakdown of carbohydrate. By means of salts and of specific inhibitors, the effect may be suppressed.

Discussion.—Dr. H. A. Krebs.

The respiratory quotient is the balance sheet of a great number of intermediary reactions. Whilst the primary reactions in which the molecular oxygen disappears are now fairly well known, the knowledge of those processes which eventually lead to the formation of CO_2 is less complete. It appears from more recent work that ketonic acids are the chief immediate precursors of the respiratory CO_2. Pyruvic, oxaloacetic, α-ketoglutaric and oxalo-succinic acids are the ketonic acids so far known to arise in the course of carbohydrate metabolism. Another series of ketonic acid arises from amino acids. CO_2 is formed from ketonic acids by ' decarboxylation.' Decarboxylation of α-ketonic acid in animal tissue is always oxidative. In many cases the oxidative decarboxylation is coupled with reduction of another molecule of ketonic acid (dismutation) :

$$\begin{array}{lclclclcl}
\mathrm{R} & & \mathrm{R'} & & & & \mathrm{R} & & \mathrm{R'} \\
| & & | & & & & | & & | \\
\mathrm{CO} & + & \mathrm{CO} & + & \mathrm{H_2O} & = & \mathrm{CHOH} & + & \mathrm{COOH} + \mathrm{CO_2} \\
| & & | & & & & | & & \\
\mathrm{COOH} & & \mathrm{COOH} & & & & \mathrm{COOH} & &
\end{array}$$

In certain bacteria (staphylococcus) all the respiratory CO_2 appears to be formed in this way. In animal tissues a considerable fraction, the magnitude of which varies from tissue to tissue, arises from dismutations of this type.

Dr. T. Mann.

Two fundamental chemical processes are involved in the fermentation and respiration in animal and plant tissues: transfer of hydrogen and transfer of phosphate.

These processes require several catalysts known as the oxidizing and phosphorylating enzymes. Coupling of oxidations with phosphorylations was shown recently in animal tissues, yeast, bacteria (Meyerhof, Needham, Lipmann). Until a few years ago research on the mechanism of enzymic oxidations and phosphorylations was carried out mainly on tissue slices and/or cell-free extracts. More recently, however, attempts were made to study fermentation and respiration in systems composed of purified enzymes, coenzymes and substrates. Whereas the isolation of some of the oxidizing enzymes has been successfully accomplished, the enzymes concerned with phosphorylations still await their final purification.

The introduction into research of 'isolated enzyme systems' has already proved of greatest value in the field of fermentation and respiration.

Dr. J. H. Quastel.—Narcotics and tissue respiration.

Narcotics, contrary to early conclusions, have specific effects on tissue oxidising systems. At low concentrations they greatly inhibit the oxidation by brain tissue of glucose, lactate and pyruvate, but not that of succinate or α-glycerophosphate. Cytochrome oxidase is unaffected. Their inhibitive effects on brain respiration in presence of glucose are definite at narcotising concentrations, the inhibitions being more marked using brain cortex slices than when using minced brain. At relatively high concentrations they compete with lactate for its dehydrogenase according to mass action laws, as shown by the methylene blue technique. At the low concentrations which markedly inhibit brain tissue respiration, there is little or no inhibitive effect on the known dehydrogenases under anærobic conditions. Thus pyruvic dehydrogenase is unaffected by relatively low concentrations of narcotics. Narcotic inhibitions ærobically are steady and reversible (at normal or high potassium ion concentrations). They are dependent on the concentration of narcotic and not on the concentration of substrate to which the tissue under examination is exposed. Narcotics at low concentrations particularly affect the pyruvic acid oxidising systems in brain, kidney or diaphragm. It is suggested that there is a factor or dehydrogenase (possibly analogous to diaphorase) highly sensitive to narcotics which acts as a hydrogen carrier in tissue respiration between pyruvic dehydrogenase and cytochrome oxidase.

Dr. S. Ochoa.—Carbon dioxide evolution and cocarboxylase.

There seems to be, down to the pyruvic acid stage, a main common path for both anærobic and ærobic breakdown of carbohydrate in animal tissues. The phosphorylated triose is oxidised anærobically by dismutation, ærobically, by giving up hydrogen to the cytochrome system through coenzyme I, flavoprotein, and C_4 dicarboxylic acids. The phosphorylated oxidation product (phosphoglyceric acid) yields pyruvic acid which, anærobically, is reduced to lactic acid. So far carbohydrate oxidation is accomplished by hydrogen transfer to oxygen, water being formed. Aerobically, however, pyruvic acid is not reduced but decarboxylated and oxidised, the second final product of respiration, carbon dioxide, being set free at this stage. It has recently been demonstrated in Oxford that the oxidative decarboxylation of pyruvic acid in animal tissues (brain) is catalysed by cocarboxylase (vitamin B_1 pyrophosphate). 1 mol. cocarboxylase catalyses optimally the uptake of 1500 mols. O_2 (production of 2000 mols. CO_2) per minute, the lowest active concentration being approximately 5×10^{-9} M., the maximum $1 \cdot 5 \times 10^{-7}$ M. The complete oxidation of pyruvic acid also requires at least inorganic phosphate, adenylic acid, fumarate, and coenzyme I. The oxidative decarboxylation yields

carbon dioxide and apparently a compound with the empiric formula $C_2H_4O_2$ which may appear as acetic acid in the absence of the rest of the enzyme system. As adenylic acid is indispensable for the further oxidation, it appears that here again a phosphorylation cycle is involved.

The question whether cocarboxylase is active only in catalysing the decarboxylation of pyruvic acid or also as a hydrogen transporting coenzyme cannot yet be answered.

Prof. H. S. Raper, C.B.E., F.R.S.—The control of tissue respiration.

Experiments on isolated organs using blood gas analysis have shown that activity is accompanied by increased oxygen consumption. It is not known how the new rate of oxidation is regulated. The participants in the oxidation are the catalysts, the oxidisable substrate and oxygen. Increase in any one of these might conceivably increase oxidation in a system previously in a steady state.

The problem has been approached by using cat's submaxillary gland slices which show an increased uptake of oxygen in the presence of acetyl choline. The experimental data suggest that neither increase of substrate nor oxygen supply is a cause of increased oxidation under normal conditions. It is probably therefore conditioned by changes in the availability of the catalyst. The fact that the resting respiratory activity has different properties from that of the tissue stimulated by acetyl choline also suggests that a change in the state of the oxidation catalysts is responsible for the changed oxygen uptake. This may be true for the submaxillary gland but not necessarily for other tissues.

Dr. E. P. Poulton.—Local tissue anoxia.

In ' Local Tissue Anoxia ' some tissues are starved of oxygen owing to arterial disease, etc., though the saturation of the arterial blood is normal. This can be investigated in man by means of an oxygen tent with 60 to 80 per cent. oxygen for days on end, since it has been shown that in these circumstances the nitrogen dissolved in the tissues diffuses out of the body, while oxygen diffuses in. The known examples of local tissue anoxia are : varicose ulcer, two cases, poisoning by alcohol (and cyanide) and coronary thrombosis, which have already been investigated in this manner. But the myocarditis of acute rheumatism provides one of the most striking examples. The patient feels better in the tent, the temperature and pulse fall to rise again if the tent is removed ; there are modifications in the auscultatory signs ; the electrocardiographic tracings are changed, while the heart becomes smaller. In those cases where the blood lactic acid is high (in some cases low values are obtained) there is a marked fall in the tent, and a rise if the tent is removed too soon. The period in the tent has varied between a week and eighty-two days.

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Discussion on New technique in physical chemistry.

Dr. H. W. Melville.—Introduction.

Prof. S. Sugden, F.R.S.—Radioactive indicators.

The experimental methods used in preparing artificial radio-elements and in measuring their radioactivity are briefly reviewed and the properties which facilitate or hinder the use of a particular element are considered. The chemical applications include a discussion of (*a*) the detection of ionic compounds in which the exchange of radioactive atoms with inactive atoms takes place with a speed too high to be measured, and (*b*) the study of exchange reactions which involve the breaking of a covalent bond and proceed at a measurable speed.

Prof. W. F. K. Wynne-Jones.—Isotopes as atom indicators for reactions in solution.

It has always been of great interest to chemists to find out what happens to particular atoms when molecules undergo chemical change. Ordinary chemical analysis fails to solve this problem when there are several atoms of the same kind, and the numerous theories which have from time to time been advanced to explain the phenomena of chemical change have lacked experimental basis.

The possibility of obtaining isotopic forms of the common elements has afforded a means of experimental attack on this problem, and the isotopes of hydrogen, oxygen and nitrogen have all been used to examine the mechanism of chemical reactions.

The use of deuterium, the isotope of hydrogen, has made possible the study of labile hydrogen atoms and of acid-base catalysed changes. The mechanism of neutralisation, enolisation and mutarotation have all been studied and elucidated in this way.

The application of the other isotopes has already proved fruitful, and the interchange of oxygen atoms between molecules as well as the mechanism of hydrolysis of esters have been examined with success.

The scope of these studies is so wide that the development of methods of separating and detecting isotopes has become a matter of great importance to all chemists.

Dr. M. Ritchie.—Reaction of free atoms.

Many photochemical reactions involving molecular halogen proceed by way of atomic halogen. In the quantitative determination of reaction mechanism it is therefore of prime importance to know precisely how such atoms recombine. Indirect estimates have been made from reactions the mechanism of which has been fully established. Another method consists in measuring the decrease in extinction coefficient when molecular halogen is irradiated with light of known intensity. The third method consists in the measurement of the Budde Effect, that is, the pressure increase observed on irradiating halogen vapour. By further development of the technique it is now possible to deduce accurately the mechanism of the reaction and the magnitude of the velocity coefficients.

Prof. T. Alty.—Accommodation coefficients.

The paper discusses the recent work done on the measurement of accommodation coefficients, condensation coefficients, and evaporation coefficients. It gives a brief account of the methods of measurement of the coefficients, the results obtained, and the importance of these results for theories of the interaction of gas molecules with surfaces, the mechanism of crystal growth from the vapour, etc. The use of the accommodation coefficient method for the study of adsorption on metal surfaces and the measurement of heat of adsorption is described.

Dr. H. W. Melville.—Recent technique in photochemistry.

Gaseous photochemical reactions have mainly been investigated by examining what effect such factors as pressure, temperature and products have on the quantum yield of the reaction. Such an examination is often limited in its scope. In the present paper, therefore, an account is given of the development of a number of new methods such as multiple light sources, rotating sectors, etc., for obtaining new information about simple photochemical reactions. In particular the application of these methods to problems in the photochemistry of hydrides is discussed.

Discussion on Light alloys.

Dr. C. H. Desch, F.R.S.—Introduction.

Of the metals of low specific gravity only three, aluminium, magnesium, and beryllium, have properties which fit them for use as structural materials. Beryllium has not so far been obtained in a massive ductile form, and even as an alloying element it has not been found possible to make use of its property of lightness. The modern alloys of aluminium have mechanical properties comparable with those of structural steel, whilst their resistance to chemical influences is in many instances very high. The improved properties are obtained by thermal treatment, the phenomenon of 'age-hardening' having been first observed in an aluminium alloy and having opened up a new field of research on metallic systems, besides furnishing the engineer with a new range of useful materials.

The growth of the light alloy industry has been remarkably rapid, and has been accelerated in certain countries by the desire to find substitutes for imported metals. The same desire has been largely responsible for the rapid recent development of alloys of the still lighter metal, magnesium, which may be produced from widely distributed and easily accessible minerals. These alloys, although less resistant to chemical attack, may be protected by surface treatments, and find a wide range of applications.

Dr. A. G. C. Gwyer.—The constitution of aluminium alloys.

The constitution of the binary alloys of aluminium has been studied sufficiently to make some form of classification desirable. The systems so far investigated may be divided into eight classes, in each of which the constitutional diagrams show interesting and, in some cases, striking similarities. With few exceptions, the alloying elements in one of these classes belong to the same group in the periodic classification. Thus the alkali metals, with the exception of lithium, form one class, while the alkaline earths, together with lithium but excepting beryllium, form another.

There are also a number of thermodynamic relations between the properties of the binary alloys of theoretical interest and practical value.

The ternary and higher alloys have not yet been thoroughly investigated, and are mostly very complex.

Relatively few of the elements form commercially useful alloys with aluminium, and in all but one or two cases these are hypoeutectic alloys since, once the eutectic composition is exceeded, the presence of a hard constituent results in loss of ductility. The most commonly used alloying elements show more or less marked solid solubility. This hardens the aluminium matrix and gives scope for improvement by age hardening.

The degree of dispersion of hard constituents markedly affects ductility, and in one technically important case, that of the aluminium silicon alloys, this can be controlled by a process known as 'modification.'

Prof. A. von Zeerleder.—The light alloys of aluminium.

The light alloys of aluminium fall into two classes: those which are used in the original cast or wrought condition, and those which are given their improved properties by heat treatment. Cast as well as wrought alloys appear in both classes. Castings are made in sand and in cast-iron moulds, whilst die-castings are made both by the gravity and the pressure method. Wrought light alloys are worked by rolling, forging, spinning, and drop-forging, the great deformability of the alloys being of advantage. The various classes of aluminium alloys and their specific fields of application are briefly reviewed. The special characteristics of these alloys include light weight, high thermal conductivity, and high reflecting power for light and heat.

Mr. W. C. Devereux.—Industrial research methods for light alloys.

An industry of recent origin, such as that of the alloys of the light metals, is dependent in an exceptional degree for its progress on active research. Both fundamental and industrial research are needed, and in this instance the value to industry of fundamental research on metals and alloys is in the long run at least as great as that of investigations having a direct practical object. A strong plea is made for a great extension of research in the field of the light alloys.

The general course of the work in the author's own research department is described, being concerned with the production of improved light alloys of aluminium and magnesium, and with a study of their properties under varying conditions of manufacture and service. The procedure is largely based on the data provided by fundamental research, and many of the methods developed by the 'pure' research worker are employed. Reference is made to the use of crystal analysis by X-ray methods for the study of hot and cold working and for the determination of internal stress, to the development of quantitative spectrographic analysis, and to the use of sonic and supersonic methods of detecting flaws in manufactured components.

* * *

Dr. H. W. Melville.—New lamps for old.

This lecture is a survey of the methods for the production of artificial radiation accompanied by experimental demonstrations. First, chemical methods for the production of light are dealt with. This includes luminous and non-luminous flames and the development of selective radiators up to high-pressure incandescent gas lighting. Next follows some demonstrations of the production of 'cold light' or chemiluminescence. The second part of the lecture deals with physical methods for the production of light. The development of filament lamps is described. This is followed by demonstrations of the principles of the production of light by electric discharges in rarified gases leading finally to the most recent types of fluorescent discharge lamps.

* * *

Discussion on Intramolecular change involving the migration of groups.

Prof. A. McKenzie, F.R.S., and Dr. R. Roger.—Introduction.

The authors discuss, among other problems, the question of semipinacolinic deamination and semipinacolinic dehydration with *optically active* amino-alcohols and *optically active* glycols.

Prof. M. Tiffeneau.—Aptitudes migratrices et capacités affinitaires des radicaux non-saturés dans les transpositions moléculaires.

L'influence exercée par les radicaux sur les transpositions moléculaires des α-glycols et de leurs dérivés se manifeste soit par leur *capacité affinitaire* ou leur électro-négativité relative (celle-ci intervenant pour rendre moins stables les substituants voisins (hydroxyle ou liaison époxydique), soit par leur *aptitudes migratrices*, celles-ci étant dans un certain rapport avec les capacités affinitaires.

Il est bien établi que les aptitudes migratrices des radicaux aromatiques (tous fortement électronégatifs) l'emportent sur celles des radicaux aliphatiques. De même, pour les radicaux aromatiques comparés entre eux, on constate que, à quelques exceptions près (notamment phényle > *p*-tolyle, McKenzie, 1930), ce sont les plus électronégatifs qui ont les plus fortes aptitudes migratrices. Par contre, dans le cas des radicaux aliphatiques, ce sont les moins électronégatifs qui émigrent de préférence. Cette difference de comportement n'est pas encore éclaircie.

L'étude des radicaux non saturés a montré que ceux-ci interviennent différemment suivant leur nature.

Le vinyle, $-CH : CH_2$, se comporte comme les radicaux à forte capacité

affinitaire, non seulement en rendant moins stable l'hydroxyle voisin (glycols) ou la liaison époxydique voisine (époxydes), mais aussi en émigrant de préférence au méthyle et même à l'éthyle (Deux, 1939).

$$C_6H_5\text{—}\overset{\downarrow}{C}H \;\; I \text{—}COH(R)CH : CH_2 \rightarrow C_6H_5(CH_2 : CH)CH\text{—}CO\text{—}R \; ;$$
$$R = Me \text{ ou } Et.$$

Il n'en est plus de même lorsqu'on oppose un diméthyl-vinyle (Dmv) au méthyle ; les aptitudes migratrices de ce dernier l'emportent exclusivement ce qui permet de supposer que le diméthyl-vinyle se comporte comme un radical aliphatique à capacité affinitaire plus élevée que celle du méthyle et de l'éthyle, des lors, ceux-ci émigrent de préférence (Deux, 1939).

$$Dmv(Me)\overset{\downarrow}{C} \cdot OH \text{—}C(OH)\;(Me)Dmv \rightarrow Dmv(Me)_2C\text{—}CO\text{—}Dmv$$

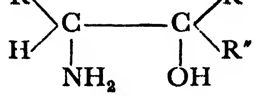
Ainsi la forte attraction électronique qui caractérise le radical vinyle et le rapproche du phényle, tend à diminuer par les substitutions méthylées si bien que le diméthyl-vinyle semble fonctionner comme un radical aliphatique à forte capacité affinitaire et à faible aptitude migratrice.

Dr. S. F. Birch.—The catalytic isomerisation of paraffins.

Until comparatively recently little attention has been paid to the isomerisation of the simplest hydrocarbons, the paraffins. This has largely been due to their apparent inertness under all but the most drastic conditions. Recent investigations have, however, shown that certain *iso*paraffins, particularly the more highly branched members, are surprisingly reactive, and are readily attacked by such reagents as aluminium chloride and sulphuric acid at room temperatures. Even the more inert normal paraffins are isomerised under comparatively mild conditions by the aluminium halides, aluminium bromide being particularly effective in converting normal butane into *iso*butane at ordinary temperatures. The mechanism by which such rearrangements take place is obscure, but there is some evidence that complex formation between the halide and hydrocarbon is an essential preliminary step. Since such complex formation would tend to weaken C—C bonds it is only to be expected that under such conditions rearrangement would take place to a thermodynamically more stable form. The fact that isomerisation is usually accompanied by the formation of higher and lower molecular weight *iso*paraffins indicates that fission of the carbon chain takes place and is followed by recombination of the fragments to form new hydrocarbons, a probable explanation for the isomerisation mechanism. This tendency for breakdown and recombination to occur is especially noticeable with the higher more highly branched *iso*paraffins such as 2.2.4—trimethylpentane. So unstable is this hydrocarbon that when vigorously agitated with sulphuric acid for a prolonged period it is converted into a complex mixture of *iso*paraffins.

Dr. A. K. Mills.—The stereochemistry of intramolecular change.

The action of nitrous acid on an amino-alcohol of the type



leads in most cases to the formation of a ketone, $\genfrac{}{}{0pt}{}{R'}{R}\!>\!CH\cdot CO\cdot R''$, and involves the

migration of a radical. In the case of an optically active amino-alcohol the resulting ketone is isolated in a high degree of optical activity. A study of the deamination of optically active amino-alcohols has been carried out in order to obtain further information as to the nature of the reaction. It has been proved in a number of cases that the migrating group occupies the same relative position after migration and some evidence is forthcoming as to whether a Walden inversion is involved or not.

A number of pairs of diastereoisomeric amino-alcohols of the above type have also been deaminated and it has been found that either R′ or R″ may migrate according as to whether the α- or β-form of the amino-alcohol is deaminated. The migration appears to be controlled by the relative positions of the groups.

Other transformations have also been studied involving the migration of the optically active radical $\begin{matrix}C_6H_5\\CH_3\end{matrix}\Big\rangle CH-$ and retention of optical activity.

Dr. T. S. Stevens.—A general type of intramolecular rearrangement.

The thermal rearrangement of amino-oxides (Meisenheimer) is typical of many in which (formally at least) the ‘ destination ’ of the migrating radical is a lone electron-pair :

$$:\underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}:\underset{\underset{R}{\cdot\cdot}}{\overset{\overset{Ph}{\cdot\cdot}}{N}}:Me \rightarrow :\underset{\underset{R}{\cdot\cdot}}{\overset{\cdot\cdot}{O}}:\underset{\cdot\cdot}{\overset{\overset{Ph}{\cdot\cdot}}{N}}:Me$$

contrast the Whitmore scheme in which the destination is an incomplete octet.

In general terms we have

$$\underset{\cdot\cdot}{A}-\underset{\underset{R}{\cdot\cdot}}{B} \rightarrow \underset{\underset{R}{\cdot\cdot}}{A}-\underset{\cdot\cdot}{B}$$

and cases have been realised in which A—B is $\overset{-}{O}-\overset{+}{N}$, $\overset{-}{C}\equiv\overset{+}{N}$, $\overset{-}{N}-\overset{+}{S}$, $S-O$, $\overset{+}{S}-O$.

Further the lone pair on A may arise through the removal of a proton by an alkaline reagent :

$$PhCOCH_2\underset{\underset{R}{|}}{\overset{+}{N}}Me_2 \xrightarrow{NaOH} PhCO\overset{-}{C}H\underset{\underset{R}{|}}{\overset{+}{N}}Me_2 \rightarrow PhCO\underset{\underset{R}{|}}{C}HNMe_2$$

and we can thus add the cases $\overset{-}{C}-\overset{+}{N}$, $\overset{-}{C}-\overset{+}{S}$, $\overset{-}{C}-N$, $\overset{-}{C}-O$. The formal analogy between these diversified changes is reinforced by the similar influence of analogous structural alterations on the course of the reaction.

To many of these rearrangements there correspond formally analogous *inter*-molecular migrations of groups, but it is possible to doubt if these analogies are more than formal.

METAMORPHISM AND IGNEOUS ACTION

ADDRESS TO SECTION C.—GEOLOGY

By Prof. H. H. READ, D.Sc., F.R.S.

PRESIDENT OF THE SECTION.

Und dass mich zuweilen bedünken will, gar manche der vielgepriesenen Wunder des Metamorphismus dürften recht passenden Stoff zu einem 16. *Buche der Ovidischen Metamorphosen liefern.* (C. F. Naumann, 1858.)

On many counts it is fitting that the subject of the metamorphism of rocks should be dealt with at a meeting in Dundee. In the first place, on November 14, 1787, there was born at Kinnordy, near Kirriemuir, less than a score of miles north of this city, that self-confessed ' loudest and most indefatigable squaller of all the brats of Angus ' who gave us the term itself—I refer, of course, to the illustrious Charles Lyell. Again, beyond Kirriemuir and the lowlands of Strathmore, which are underlain by the Old Red Sandstone, most Scottish of rock-formations, begin the Highlands, composed for the greater part of metamorphic rocks. Time was when marauders from these fastnesses raided the fatter lands of the south, and a body, worthy perhaps of a more dignified title, once penetrated as far as Derby. It is a matter of observation that their modern and, on the whole, more polite descendants still take the English road and, moreover, have reached still farther south. But when we consider the geological traffic, the movement is and always has been in the reverse direction. For a century, English geologists have been attracted by the unlimited scientific riches of the Highlands. They have penetrated as yet only as single spies ; they will come I hope as battalions—for there is loot for all. Who knows but that the true value of this invasion from the south far outweighs the more material spoils which are sent northwards by the Scots ?

Among these English invaders, I wish to single out George Barrow (1853–1932), who, in the Highlands of Angus, Kincardine and Aberdeen, north of this city, made discoveries so far in advance of his time that they have only recently been rediscovered. Barrow made mistakes too ; let those who would belittle his work on this account ponder Edward Greenly's ' Orders of Validity in Geological Theory '—but he contributed many major ideas to metamorphic geology, ideas concerned with metamorphic zones, with filter-press action in igneous injection, with the relation between metamorphism and igneous intrusion, and so forth. Bearing in mind the main theme of these present remarks, I desire to pay this tribute to Barrow's work and memory.

To Lyell, who introduced the term in 1833, ' metamorphic ' meant transformed. In that he coined a special word, it seems clear that he did not intend all rock-transformations to be included in metamorphism. Some modern extensions of metamorphism to cover weathering, cementation, and the like appear to destroy whatever justification Lyell's special term had. From the beginning Lyell considered that metamorphism was closely

connected with some kind of igneous activity. The metamorphic rocks 'had been modified by plutonic agency under pressure in the depths of the earth.' Again, 'they must lie at the bottom of each series of superimposed strata, because the influence of the volcanic heat proceeds from below upwards.' In the *Principles* it is stated that, in metamorphism, 'the transmutation has been effected by the influence of subterranean heat acting under great pressure, and aided by thermal water or steam and other gases permeating the porous rocks, and giving rise to various chemical decompositions and new combinations.' In the *Elements* of 1838, the importance of magmatic gases is clearly expressed. Such gases are considered to have permeated the earth's crust in a belt 'thousands of fathoms in thickness,' and it is suggested that 'their heating and modifying influence may be spread throughout the whole of this solid mass.' Lyell's views, written a century ago, bear a strangely modern look.

In the development of ideas on metamorphism since Lyell's time, we see emphasis laid upon the dominance in rock-transformation of one physical factor or the other, as in the expressions dynamic metamorphism and thermal metamorphism, or upon spatial considerations, as in regional metamorphism or local metamorphism. The content of metamorphism becomes enlarged to include weathering and the like, or contracted to exclude simple crushing. Recrystallisation is regarded as an essential in metamorphism by one master, and as not requisite by another. According to one school, the chemical composition of rocks undergoing metamorphism is not changed; according to another it can change to almost any extent. The definition of the term itself, and of the phases of metamorphism, are the subjects of dispute. This lack of uniformity, which still exists, may give pain to some, but for my part I regard it as a sign of vigorous growth—metamorphic geology without controversy would be moribund. Moreover, I appreciate fully and often a remark of Jacques de Lapparent, 'le bon-sens d'aujourd'hui, qu'on nomme parfois vérité, n'est pas nécessairement le bon-sens de demain.'

This diversity of opinion is due to certain fundamental and human causes. The development of an observational science like geology depends upon the personal experience of individual workers. I suggest that, with certain reservations that need not be considered at this moment, the best geologist is he who has seen most rocks. In the rather intricate field of metamorphic geology, specialisation comes early and continues. A metamorphic geologist who has investigated a Scottish injection-complex, for example, spends his vacations visiting injection-complexes in Finland, the Pyrenees, and elsewhere: his view of the whole field of metamorphism is coloured by his knowledge of injection-complexes; if the reader persists to the end of this Address he may recognise an example of this.

This limited experience, in even the most competent geologists, has left its mark on the flux of ideas on metamorphism. We find there the personal experience of the masters, restricted though it must be, giving a bias to their concepts of the whole field of rock-transformation. This led to the rise of schools of thought which were, curiously enough, markedly nationalist in character. A brief examination of these national schools will serve to show the development of metamorphic geology, so far as my special topic is concerned, prior to the Great War.

In 1877, Rosenbusch of Heidelberg published his classic account of the thermal or contact metamorphism around the Barr-Andlau granite in the Vosges. He found there no evidence for transfer of material from the intrusive granite into the surrounding country-rocks, and proceeded to apply his conclusions to all granite contacts: permeation by magmatic juices was impossible. The great authority of Rosenbusch led to the adoption of this doctrine not only in Germany, but also in other countries; we find it still lingering in our own. Meanwhile, Lossen (1859), Lehmann (1884), and others in Germany had dealt with rocks in which movement was held to be responsible for their metamorphism, and Lossen had proposed the term dislocation-metamorphism for what Rosenbusch later called dynamic metamorphism. For Rosenbusch and the orthodox German school, therefore, there were two kinds of metamorphism,—first, contact-metamorphism of Barr-Andlau type, and second, dynamic metamorphism in which pressure was the operating factor, this pressure being essentially orogenic in character. Even in Rosenbusch's own time, some of his compatriots, such as Lehmann himself, resisted his dictatorship, and during the first decade of the present century many examples of transfer at granite contacts, injection and assimilation, had been described by German workers, e.g. Chelius, Erdmannsdörffer, Gäbert, Gurich, Klemm, Lepsius, Philipp, Sauer, Schwenkel, Steinmann, Weber and others.

In France there had developed meantime a powerful school with tenets completely opposed to those of Rosenbusch. As early as 1844, Violet d'Aoust had used the expression *roches d'imbibition*, an expression that has played a great part in French ideas on metamorphism ever since. From their studies, during the '80's and '90's, of granite contacts in the Pyrenees, Brittany, and elsewhere in France, Michel-Lévy, Lacroix, Barrois, and others concluded that the country-rocks adjacent to the advancing magma had been changed in chemical composition by the influence of mineralising agents, volatiles and solutions, so that finally they approached granite in character. The original granitic magma (not to be confounded with the granite rock) combined with the country-rocks either by imbibition (permeation) or by lit-par-lit injection. Passages from country-rock through mica-schists of various types to granite-gneiss, gneissose granites, and finally granite, were described. The original granitic magma advanced by conversion of its country-rock into granitic material and the incorporation of this into the main body of moving magma. Granitisation or felspathisation was established as a petrogenetic process.

Many of the products of these injection and granitisation processes were foliated or gneissose in structure. According to the French, therefore, gneisses were not the result of a dynamic metamorphism in which the source of the heat was to be sought in the mechanical work produced during folding, as Lehmann and other German authorities believed, but such rocks derived the heat necessary for their formation from the uprise and injection of magmatic material. As Michel-Lévy remarked, contact metamorphism at considerable depths becomes confluent with regional metamorphism.

The bitterest opponent of dynamic metamorphism among the French, however, was Termier (1903, 1910). In 1903 he declared, 'le dynamométamorphisme n'a pas maintenant d'adversaire plus acharné que moi,' and proposed that the term should be abolished. Dynamic action deformed, but it did not transform, and mylonitic rocks were its only product. Termier's

views with regard to regional metamorphism and granitisation differed in many respects from those of his countrymen. He agreed that no one could reasonably doubt that in the formation of the true crystalline schists there had been an afflux of elements from the depths which had chased the old elements before them, and that many gneisses, especially those containing xenoliths (segregations according to Termier) had attained some slight degree of fluidity which permitted an orientation of their components. He agreed also that the production of the crystalline schists was concerned with depth of burial in the geosyncline, but that depth alone was not sufficient. The causative factor was the arrival from below, in *colonnes filtrantes*, of juvenile liquids bringing with them various gases, silicates and borates of the alkalies ; the temperature of the geosynclinal sediments increased rapidly, eutectic mixtures went into solution first, the old elements in excess of the eutectic proportions fled before the *colonne filtrante* and displaced other elements in their turn ; true magmas were formed here and there—of all dimensions, increasing with depth ; in the upper parts, the geosynclinal sediments were recrystallised without change of chemical composition, and passed downwards into gneisses and, upwards and laterally, into less metamorphosed rocks ; the still liquid ' magmatic ' portion was intruded at higher levels in cross-cutting form. Termier employed his famous metaphor : the production of regional metamorphism can be likened to the unequal spreading of a spot of oil in a pile of cloths, the spreading being governed by the different permeabilities of the layers of the pile. Regional metamorphism, therefore, was not caused by igneous intrusion ; it was not a more extensive form of contact metamorphism. When regional metamorphism and igneous intrusions occurred together, they were two effects of the same cause, the rise of the *colonnes filtrantes*. The production of igneous rocks was only an episode in regional metamorphism. In Termier's beliefs we see the germs of many doctrines of to-day.

Turning now to the contributions from Austria and Switzerland, we must acknowledge the pre-eminent work of Becke of Vienna, especially in the petrography of the metamorphic rocks. In dealing with the crystalline schists of the Waldviertel (1910) he wrestled with one of the great problems of metamorphic geology—a problem that we shall encounter again and again in this Address—and that is, the coincidence of schistosity with primary structures such as bedding, and the horizontal attitude of such metamorphic rocks over considerable areas. He found it difficult to explain the widespread horizontal schistosity by tangential pressures, but the parallel structures seemed scarcely understandable without invoking directed pressure of some kind. He suggested the operation of something akin to contact-metamorphism—not related to any visible igneous body, but rather due to the hot interior of the earth ; only local injection-metamorphism was observed by him in the Waldviertel. Here we have a return to ideas as old as Hutton. Thirty years before, Becke had considered that two types of dynamic metamorphism were recognisable, one at shallow depths, which gave rise to propylitic rock-types (the epi-schists of present-day nomenclature) and another at much greater depths which yielded products like those of contact-metamorphism. In 1903, in one of the most outstanding contributions to metamorphic geology of any age or country, he developed these ideas on depth zones—ideas which now play so fundamental

a part in the study of the metamorphic rocks. In 1878 Heim of Zürich had distinguished between an upper zone of the crust in which rupture took place, and a lower zone of plastic flow; twenty years later, van Hise of U.S.A. examined the physical-chemical factors in the two zones, the upper of fracture, the lower of flow, and showed that in a general way reactions took place in the upper zone with liberation of heat and increase of volume, and in the lower zone with absorption of heat and decrease of volume. Becke, in his remarkable paper of 1903, showed how the mineral associations and textures of metamorphic rocks depended upon the pressure-temperature conditions prevailing at the time of their formation. He utilised the Volume Law, first proposed by Lepsius (1893), to demonstrate that increase of pressure led to the formation of minerals of higher specific gravity; pressure increased with depth. Temperature, too, increased with depth, and the most important cause of this was the approach to the internal heat of the earth. Becke gave two zones, an upper, where the formation of hydroxyl minerals was possible, and a lower, where hydroxyl minerals could not be formed. Becke's zones have been expanded, elaborated and defined, chiefly by Grubenmann and Niggli of Zurich. In the upper, or epizone, temperature was low, hydrostatic pressure small, directed pressure either very strong or lacking, and the style of the metamorphism is dominantly mechanical with the formation of hydrous silicates; in the mesozone, the temperature was higher, hydrostatic pressure higher, directed pressure weaker and the metamorphic style is characterised by chemical reactions; in the deep or katazone, temperature was very high, hydrostatic pressure very high, directed pressure weak or absent and the metamorphic style is characterised by the presence of many minerals akin to those of igneous rocks and by a but poorly-developed schistose texture. Suggestions of the depth control of metamorphism are as old as Lyell, and references to shallow and deep zones of metamorphism are abundant throughout the history of metamorphic geology. In my opinion, the association of depth with metamorphic zones of this type, as in the expressions depth-zone and Tiefenstufe, may occasionally lead to unfortunate results. I return to this topic in later pages, but I may remark here that *Tiefenstufe* at least does not occur in the index to Grubenmann-Niggli's *Die Gesteinsmetamorphose* of 1924.

I return to Switzerland in my historico-nationalist amble through Europe, to mention certain ideas first of Weinschenk and then of Koenigsberger. Weinschenk (1901, 1902), in dealing with the granitic gneisses of the Alps, was concerned with a very old question indeed, namely, whether such gneisses are completely primary igneous rocks. The intrusive masses must have exercised a metamorphic action upon the adjacent rocks, and the sedimentary cover retained its original structures on this metamorphism—a circumstance readily explained by contact-metamorphism, but rather difficult to harmonise with dynamic action. The difference between ordinary contact-metamorphism and the Alpine metamorphism of Weinschenk is the evidence for the activity of great pressures during the latter and the tendency of the rocks produced thereby to occupy less volume; recrystallisation after folding is often demonstrable. To explain these observations, Weinschenk suggested that orogenic pressures were operative during the intrusion and solidification of the granitic magma. Under such oriented pressures, the magma kernel was compressed, the early-formed minerals were oriented, and minerals of smallest molecular

volume were formed—all typical of a process styled piezo-crystallisation by Weinschenk. Further, as the magma continues to solidify under pressure, the residual volatiles are expelled at a high temperature into the already folded sedimentary cover where they contribute to its metamorphism—a process of piezo-contact-metamorphism.

Weinschenk suggested that regional metamorphism is largely an affair of piezo-contact-metamorphism. These views did not find favour with Becke, who gave an alternative explanation—the metamorphism followed immediately on the consolidation of the magma and therefore the transformation was effected in the presence of abundant juvenile water and other mineralisers ; in such an environment, thorough metamorphism is easily achieved, whilst mechanical phenomena will be lacking. Further, Berg (1910), for example, considered that the original crystallisation from a fluid under pressure, which can only be hydrostatic, cannot be proved to be essentially different in structure from that under normal circumstances.

Koenigsberger (1910) proposed an interesting classification of the crystalline schists. The formation of crystalline schists containing such minerals as andalusite, cordierite, sillimanite, garnet, staurolite, biotite, orthoclase, etc., with sieve-structure, results from a lengthy intrusion of igneous material at a high temperature. Such rocks (let us say those of Becke's lower zone, or of Grubenmann-Niggli's meso-kata-zones) are grouped with migmatites as contact-metamorphic schists. Koenigsberger has a second group, labelled dynamo-metamorphic schists, which includes first, mylonites and second, true regional-metamorphic schists. This last-named sub-division is an interesting one ; it includes the rocks of Becke's upper zone or of Grubenmann-Niggli's epizone. Koenigsberger suggests that they should be called tele-intrusion-schists. They are formed, as it were, in the outermost parts of contact-aureoles in connection with the movement of igneous masses. It seems to me, therefore, that with the exception of mylonitic and similar rocks, the rocks of all metamorphic zones would be considered by Koenigsberger to be connected with igneous activity.

We may now proceed northwards into Scandinavia, where contributions of the first magnitude were being made to the study of metamorphism. In Finland, Sederholm (e.g. 1907, 1913, 1923, 1926) in a lengthy series of masterly memoirs based on detailed field-observation, had dealt with the complexities of the Finnish Pre-Cambrian, and had come to occupy a position very similar to that of Michel-Lévy, Lacroix and Termier in the French School. He opposed Rosenbusch and the ' micropetrological school of Heidelberg ' ; could not agree wholeheartedly with Weinschenk's views on piezo-crystallisation ; regarded Koenigsberger with suspicion and, as we shall see immediately, looked with complete distrust on certain Swedish interpretations of the Archean. Metamorphic geology was flourishing in the North.

Though Sederholm was one of the first to regard grade of metamorphism as a function of depth, he rejected the Volume Law and conclusions based upon it. Garnet, for example, could not be employed as a geological barometer. The importance of pressure in metamorphism had been grossly exaggerated ; ' the original features often remain so unchanged that not even faults of a millimeter's length may be detected.' Cataclasis is a destructive process : it does not create new minerals and rocks ; Sederholm considered the use of

the term dynamo-metamorphism to be far too wide, and recommended that it should be employed only when the facts of the case warranted. Agreeing with the French School, he recognised that solvents are essential in metamorphic changes and that they are exudations from igneous magmas. The metamorphism of the Finnish Archean was therefore regional contact-metamorphic.

Sederholm, during his long field-experience, dealt with a series of granite contacts of astounding complexity. He preferred to take granite magma as available, without considering how, where or when it might have been formed. By processes of penetration and injection, in which the magmatic juices or ichors played a large part, the granitic magma mixed with the country-rocks to give a great variety of mixed rocks,—the migmatites. Sometimes the magma advanced by Termier's *tache d'huile* mechanism ; certain permeable layers of the bedded rocks became metasomatically changed to rocks of typical aplitic or granitic composition. The process of forming granitic masses by emanations from an abyssal magma was called anatexis,—a re-fusion or re-solution ; often a rock undergoing anatexis was endowed with a new capacity for intrusion—such reborn ' magmatic ' rocks were styled palingenetic. The Finnish migmatites, like their French analogues, are often striped and foliated gneisses and inherit these textures from the original schistose rocks which have been replaced during the granitisation. Anatexis and the formation of migmatites occurred at various times in the deep Archean zone of Finland, where Sederholm suggests that denudation may have penetrated 100,000 feet, or even more.

These anatectic processes were considered by Sederholm to surpass ordinary metamorphism in potency and thus to come within what Holmquist of Sweden had called ultra-metamorphism. Anatexis implies that part of the material of the younger rock has been derived from an older rock. The question as to the importance of this part developed into a discussion between Sederholm and a Swedish school led by Holmquist, Hogbom and others. Sederholm considered the veins of the veined gneisses (his arterites) as of igneous origin, to be connected in all cases with some known granite plainly in evidence. The vanguard of pegmatitic veins advances before the great army of the granitic magma, and in some cases joins with revolutionary forces of the country invaded. In the opinion of the Swedish school of ultra-metamorphism, however, the veins were mainly exudates from the surrounding rocks—an application of the classic lateral secretion notion ; they are due to the action of revolutionaries, operating in their own country, on their own initiative, and without material help from outside. Holmquist (1907, 1908, 1910, 1920, 1921) regarded the production of veined gneisses (his venites) as a further stage of regional metamorphism, and related to the inner deformation of the rocks : they were ultra-metamorphic. True arterites, i.e. those related to igneous injections, were quite subordinate in amount, and were absent from most igneous contacts. Holmquist agreed that in regional metamorphism the rocks were flooded with solutions, and that in areas where folding and magmatic injection were contemporaneous, conditions for ' pegmatitic ' vein formation are ideal—high pressure, high temperature, and abundance of mineralisers. The difference in principle between this conception and Sederholm's anatectic re-fusion at great depths seems to me to be slight.

In his consideration of venites, however, Holmquist was not concerned only with gneisses penetrated by veins of pegmatitic aplitic or quartzo-felspathic composition, but dealt also with veins in all kinds of rocks. He showed that many veins are related in composition to the rocks in which they occur—quartz-veins in quartz-rich rocks, calcite-bearing veins in calcareous rocks, quartzo-felspathic veins in the Swedish quartzo-felspathic leptites ; clearly lateral secretion had been at work. He demonstrated thereby the processes now styled metamorphic diffusion and differentiation—processes studied especially by Stillwell, Eskola, Read, Hess, McCallien, and others. Further, in discussing the palingenetic formation of pegmatites in high-grade gneisses, Holmquist referred to the 'real fusion of the most fusible rock masses,' suggested that quartz and felspar are the first to liquify, and recalled the earlier proposals of the Americans, van Hise, Lane and Daly. This principle of selective re-fusion, again, is one which in the hands of Eskola, Wegmann, Backlund and others, has come to play an important part in petrogenesis and metamorphic geology ; I refer to it on a later page.

Before dealing with the British contributions to the development of the special aspects of metamorphic geology which concern us here, I make necessarily brief reference to contributions by North American geologists. During the period which I am considering now—up to about the Great War—American investigations of special interest to us fell into two main classes : the one essentially American and concerned with transfer at igneous contacts, the other dealing with injection-metamorphism and granitisation after the manner of the Scandinavians and French.

The association of certain ore-deposits with contact-metamorphism had been described in the Banat district of Hungary by von Cotta as early as 1865, and later von Groddeck proposed a group—those of Christiania type—formed through processes of contact-metamorphism. At the turn of the century, many large contact deposits were described and discussed from the American Cordillera and the mechanism of these pyrometasomatic deposits was placed upon a firm basis. The magnificent work of Lindgren and a score of other mining geologists in the great mining camps of Arizona, Utah, Montana and adjacent States showed that such deposits had been formed at high temperatures by emanations from igneous intrusions, usually of granodioritic or monzonitic character, which passed in great volume into the adjacent limestones. At the contacts, skarns, associations of iron-rich silicates, calc-silicates and ore-minerals, were formed ; in some cases these skarn minerals were later than the normal contact-metamorphic minerals, in others no time difference was recorded. Transfer at igneous contacts was unequivocally demonstrated. The work of the American mining geologists was of first-class importance, also, because it threw light on the processes of metasomatism or replacement, and demonstrated the control of pressure and temperature in the formation of ore deposits due to emanations from igneous magmas.

Turning now to the second group of American contributions, we may first recall that J. D. Dana in 1886 considered that gneisses had been formed by metamorphic action in which a state of re-fusion had been reached ; admittedly, Dana thought too that many other rocks, granite, norite, diorite and so forth, had arisen by the same process. The most important work of

this time, however, was that of Lawson in the Lake of the Woods (1885) and Rainy Lake (1887) areas of Canada. Lawson described annular belts of mica-schists around granite-gneiss cores ; the foliation of the cores was due to crystallisation whilst the magma was moving slowly under directed pressure, and to the same dynamic action he ascribed the production of the schistosity in the sedimentary envelope—though he cites innumerable cases where schistosity is parallel to original bedding. The granite magma was due to fusion in the deeper parts of the geosyncline. In 1910, F. D. Adams and Barlow published their important monograph on the Haliburton and Bancroft areas of Ontario, where conditions were in part very similar to those found by Lawson. They saw no reason to reject Lawson's conclusions concerning the formation of granitic magma by re-fusion and the production of foliation in the granitic gneisses by movements during intrusion of this magma ; they attributed the regularly banded gneisses to streaking-out of amphibolite inclusions during such movements. They considered that transfusion (their word) of certain constituents of the granite magma into the limestone had given rise to amphibolites and pyroxene-gneisses of various kinds and instituted a comparison with Lindgren's pyrometasomatism. Though they correlated their results with certain observations by Lacroix in the Pyrenees, they were unable to admit that sediments could be changed in situ into granite. Finally, we may quote Adams' statement at the 1910 Geological Congress at Stockholm : ' we have in the great volume of igneous magma rising from the deeper portions of the earth's crust one of the primary agencies, if not the chief agency, of metamorphism, which metamorphism may manifest itself, although with decreasing intensity, for great distances from the actual intrusion itself.' At this same Congress, Coleman declared that no case was known in Canada where metamorphism was entirely due to deep burial ; igneous rocks were always present in or beneath the sheet of sediments. These views may be contrasted with those of van Hise (1898), who admitted that the schists surrounding batholiths were identical with those considered by him to be produced by regional dynamic action ; he held that the requisite conditions—movement under sufficient pressure, moderate temperature and presence of water—were available in the two cases in quite different ways.

Before leaving this topic of the origin of gneissose banding, I desire to make reference to the stimulating paper of Fenner (1914) on the mode of formation of certain gneisses in New Jersey. Fenner described in detail a limited area of an injection-complex. He showed that the dark minerals of the granitic part had been derived from the country-rocks, that the banded gneisses were composite rocks formed by lit-par-lit injection and by absorption of magmatic material by the country-rock, and that directed pressure had not been operative. He dealt with the question of reconciling the existence of large thin tabular inclusions, standing erect and unsupported in the granitic rock—and thus denoting a viscous magma—with the undoubted permeation which demanded extreme fluidity, and concluded that gradual substitution had taken place rather than the violent intrusion usually pictured. The invasion of the magma was preceded by the advance of a wave of metamorphism into the country-rock, whose composition was changed, both by the deposition of magmatic minerals and by the removal in solution of certain of the old constituents, till it approached that of the magma itself; blocks of country-rock, so changed,

were easily assimilated by the magma. Fenner emphasised the importance of gas-fluxing on the country-rock, a topic to which he returned in 1932, as mentioned at a later stage in this Address ; a rock with pores too small to admit the main magma could admit magmatic gases.

I wish now to deal with the British contributions on the special topics of this address. We can consider in the first place Judd's concept of statical or static metamorphism, though it is true that we shall wander very far afield in this consideration. Judd (1889) recognised a tendency in his time to over-emphasise the importance and validity of dynamic metamorphism. He proposed his term statical metamorphism to cover those changes resulting from pressures which do not effect movements in the rock-masses, and are therefore related to the weight of a superincumbent load ; such changes went on at great depths and under enormous pressures. It is important to realise that Judd considered that such static metamorphism had as its most potent agency the penetration of the whole mass of the rocks by various liquid and gaseous solvents.

Judd's concept was discussed and elaborated by various geologists in Europe and America. A most important contribution was that of Milch (1894) of Breslau, in which he distinguished between dislocation-metamorphism and load-metamorphism. In the former, pressures tangential to the earth's surface were concerned, mechanical phenomena were dominant and the cause was patently tectonic. On the other hand, load-metamorphism resulted from the vertical pressure of the overlying beds and no mechanical effects were evident. Contrasted with the local and irregular development of dislocation-metamorphism, the effects of load-metamorphism were widespread. Milch drew attention once more to the old problem—the metamorphism of undisturbed beds and the coincidence of schistosity and bedding—and solved it by load-metamorphism.

In America, van Hise (1898) employed static metamorphism to cover molecular dynamic action where interchange between molecules had taken place, rather than the deformation characteristic of mass dynamic action or dynamic metamorphism. According to van Hise, the distinctive features of static metamorphism were the growth of large individuals, irregular grain-size, and the preservation of original textures. The question of the validity of static or load metamorphism has been discussed at length by Daly (1917) of Harvard, in his examination of the phases of metamorphism. Dawson (1901) had suggested that the widespread horizontality of the crystalline schists of Eastern Canada and certain features of the Shuswap rocks of British Columbia had ' been produced rather beneath the weight of superincumbent strata than by pressure of a tangential character accompanied by folding.' Daly, in his independent investigation of the Shuswap terrane, came to the same conclusions concerning the efficacy of load-metamorphism. He quoted a score of examples of areas of crystalline schists from all over the world where no evidence of crustal deformation was to be observed, where the inclination was low, foliation and bedding were coincident, and where the grade of metamorphism was not related to the degree of deformation. All these phenomena Daly felt to be ' truly inexplicable by pure dynamic metamorphism,' but readily explained by load-metamorphism. In particular, the parallelism between schistosity and bedding, no matter what the attitude of the metamorphic rocks may be,

is difficult to explain by the tangential force of intense orogenic movements. I return to the topic of load-metamorphism on a later page.

Before considering the work of George Barrow in Scotland, I may first recall the studies of certain other British investigators in injection-complexes and their views on granitisation and related topics. I have no time here to do more than mention the ideas of Clifton Ward (1875, 1876) and A. H. Green (1882) on the metamorphic origin of granite. Green suggested that ' bedded ' granite had arisen in situ by metamorphic processes, whilst ' amorphous ' granites, in which bedding had been lost, marked a more advanced stage of metamorphism ; intrusive granites were attributed to a still greater degree of energy in the transformation process. Very similar notions concerning the origin of the Lake District granites had been propounded by Ward. As we shall see, these ideas are still active though in a modern dress.

In 1896, Horne and Greenly gave an account of a portion of the great injection-complex of Sutherland in the Northern Highlands—an injection-complex with which I have been intimately concerned in recent years. They showed that a series of phenomena were coincident, namely, increases in quantity of granite in the complex, in its intimacy of relation with the country-rocks, in the grain-size of the crystalline schists and in the abundance and perfection of sillimanite. They concluded that the causes which brought about the introduction of the granite also resulted in the high-grade type of metamorphism. They believed, however, that though the granite injections were closely associated with the metamorphic processes they yet most likely found the country-rocks already crystalline schists. In discussing the origin of the foliation of the granites, they considered that the biotite folia, the foliation-makers, were relics from the country-rocks, the quartzo-felspathic elements of which had been incorporated in the granite magma.

Horne and Greenly quoted (as I did with great approval in 1925) from a report (1893–94) of Hugh Miller, junior, who dealt also with the Sutherland complex. This quotation, though lengthy, is well worth repeating : ' The structures in the granites and granitic gneisses . . . are now found to be to a large extent imitation-structures, due to a simulation of the forms and structural features of the country-rock . . . by granites that have by some means crept into their place. The process by which this replacement has been effected seems to have been, to a considerable extent, a development of crystalline matter among the granulitic materials of the pre-existing schists and quartzite. In the earlier stages of the metamorphism the granitic substance has entered or by some means suffused the structure of the stone, appearing first (in the more porous parts of the country-rock, as it would seem) as a fine mottling of granitic particles. In further stages of the metamorphism the granitic matter, keeping for the most part to the folia of the pre-existing rock, has increased in knots and knotty strings, has entered planes, slide-planes, and the lines of contortion in contorted schists (without any apparent signs of crush), and so, filling the stone, thickens into bands and sills at the expense of the original rock, until the latter, almost altogether replaced, is represented only by inclusion-planes, and ultimately by inclusion-structure. In the granites thus produced there is simulated, so far as crystalline matter can do so, the fine layering of some parts of the [country-rocks], and the coarse banding of others : there is also preserved *in cast* the rumplings and striation of

their surfaces, and to some extent also apparently their lines of cleavage . . . the inclusion-structure (as well as the inclusion-planes) everywhere retains the same dip and strike as that of the country-rock. . . . Parts of these granites are in fact, to some extent not yet defined, pseudomorphs or granite casts, preserving within portions of their mass, *as replacement structures*, the remains of the structures of the pre-existing rock.' B. N. Peach, my revered predecessor in this Chair, used to put it more briefly : the foliation in these rocks, he would say, is simply the grin of the Cheshire Cat.

In a later paper dealing with the permeation of schists by granitic material, Greenly (1903) supported the view that the extension of the magma proceeded by quiet diffusion rather than by forcible injection ; only by such a supposition could thin plane rafts of country-rock in the granite be explained. Here was an early expression of Fenner's arguments to which reference has already been made. Teall, that wise man, in the discussion on Horne and Greenly's paper, observed that though every inch of the rocks of Sutherland was alive with movement, yet the crystallisation must have taken place after the movement had ceased. Grenville Cole (1902) in his investigation of the composite gneisses of Western Ireland reached a position similar to that of the Scottish workers. The banded gneisses there were formed by the union, both mechanical and chemical, of igneous and stratified material, and the original structure of the bedded rocks was inherited by the gneisses. Later (1910) Cole referred to the production of banded gneisses as due to contact metamorphism on a regional scale.

I now take up in such detail as time allows the work of George Barrow in the Highland region north of this city. In a series of papers, reports and memoirs, appearing between 1892 and 1913, Barrow developed certain major ideas on the relation between igneous intrusions and regional metamorphism. He separated out two main epochs of granitic intrusion in Angus and Kincardine, that of the Older Granites, a series of intrusions intimately associated with the production of metamorphism of one kind or another, and that of the Newer Granites, intruded entirely later than any metamorphism and responsible for only a local and low-grade alteration of the crystalline schists already formed. Certain portions of the Older Granite magma, such as the Ben Vuroch granite, consolidated before the general metamorphism ; the hornfelses due to this early stage were for the most part destroyed by the crushing movements of the general metamorphism, but their relics were to be found in all areas flooded by this early magma. Later intrusions belonging to the Older Granite series raised the whole area to a very high temperature and were thus responsible for the high-grade metamorphism of the rocks in which they occur. These later portions of the Older Granite magma appeared in an enormous number of small intrusions, and in places they permeated the country-rocks and formed with them injection-complexes of various types. During the consolidation of many of these portions, pressure was operative, and from the partly crystallised magma were squeezed out the liquid residuals. By this mechanism there arose a north-western belt of oligoclase-biotite-gneiss, representing the material already crystallised when the pressure came into action, and a south-eastern belt of pegmatitic rocks, rich in microcline and muscovite, representing the strained-off potash-rich fraction. Differentiation by filter-press action had been at work.

At an early stage in his investigations, Barrow observed that in the areas flooded by the main Older Granite magma, the country-rocks showed an extremely high grade of metamorphism characterised by sillimanite-gneisses. Just as the Older Granite itself changed, as already noted, from the north-west to the south-east, so did the grade of metamorphism: the high-grade sillimanite zone of the north-western belt was followed south-eastwards by lower grades, first that with kyanite and then that with staurolite. Barrow (1893) considered it 'reasonable to attribute both the minerals and the crystallisation to the thermometamorphism of the intrusion.' He finally established seven zones of increasing metamorphism, marked by the incoming of an index mineral in rocks of pelitic composition. Going in from the Highland Border towards the central areas of Older Granite, he mapped out the following: (1) zone of clastic mica, (2) zone of digested clastic mica (chlorite zone of present-day nomenclature), (3) biotite zone, (4) garnet zone (almandine zone of to-day), (5) staurolite zone, (6) kyanite zone, (7) sillimanite zone. This progressive series began with slates affected by pure dynamic metamorphism and finished with coarse-grained sillimanite-gneisses associated with the Older Granitic intrusions. The whole series of zones was to be regarded as in the nature of gigantic contact-aureoles around intrusions of the Older Granite.

By this remarkable series of investigations, Barrow made three outstanding contributions to metamorphic geology, namely, those concerning filter-press action, zones of progressive regional metamorphism, and the association of high-grade metamorphism with granitic intrusions. Some of his conclusions, especially those dealing with his early hornfelsing and with the origin and metamorphic history of many of his granitic gneisses, are, in my opinion, definitely wrong, but his work has been the basis on which much modern progress has been established, and I desire, as I have done before, to pay a sincere tribute to his pioneer genius. I love, too, a bonnie fechter, and he was one of the bonniest. Like all of us, he suffered from his enthusiasms; the Older Granites were all powerful, whilst the gigantic intrusions of Newer Granite were permitted to perform nothing but a low-grade metamorphism. This aspect of Barrow's tenets was seized upon by his colleagues, and I trust I shall be forgiven, both by their author and by the manes of Barrow, if I quote two lampoons on this question which I have abstracted from the (unofficial) archives of the Geological Survey of Scotland.

The first is a verse of a lengthy poem in which the eminent members of the Scottish Geological Survey of Barrow's time are adequately dealt with. It runs:

> 'Mr. Barrow proclaimed with great volume of sound
> That the Old Magma flourishes all the world round.
> This intrusion the schists all around it does roast,
> And when it is absent it alters them most.'

The second extract is headed *Brief for Defendant in New* v. *Old Magma*, and states:

'Take an imaginary line as straight as an arrow and as broad as long from Timbuctoo to Chicago—the hornfelsing is developed all along that line.

'If the Older Granite, or any agent acting therefor, appears anywhere along that line, it proves that the hornfelsing is caused by the Older Granite.

'If the hornfelsing is absent from any or all points of the aforesaid line, it is negative evidence and proves nothing.

'If the hornfelsing occurs anywhere else than on the aforesaid line, it is not real hornfelsing.

'If the Newer Granite appears on or about the line, it proves that it has nothing to do with the hornfelsing.'

Whilst we smile at these japes now, let us hope that posterity will deal with the ideas of each of us as kindly as present-day metamorphic geologists are dealing with Barrow's.

I have now come to the end of my travels through the space and time of the development of metamorphic geology up to 20 years ago. I have endeavoured to place before you the pertinent contributions from the nations. I have, for obvious reasons, been compelled to make a selection, and in these queer times I am constrained to apologise to any individual or nation that feels aggrieved at its nature. We may now pass on to a discussion of the major ideas so briefly stated, and of their modern derivatives.

The student of metamorphism learns very early that there is no kind of uniformity in the classification and definition of rock-transformations. He finds one dichotomy based upon space, as in regional and local metamorphism, another on mechanics as in static and dynamic or static and kinetic metamorphism, a third on geological considerations, as in Grundgebirge and Deckgebirge metamorphism, and so forth. Furthermore, when he considers any particular type of metamorphism, he realises that whilst it may be possessed of an honest-looking title, yet this honesty is liable to become somewhat blown-upon when the numerous definitions concerned are examined.

This is specially evident in connection with the term regional metamorphism, where several branches of different dichotomies become intertwined. The only common denominator in definitions of regional metamorphism—and one at least I feel we are entitled to expect—is that such metamorphism affects rocks over extensive areas. This having been admitted by all, then alleged genetic considerations come into play.

Some geologists, Daubrée and Termier for instance, require that regionally metamorphosed rocks should arise by the action of hot emanations on deeply buried rocks ; others, including Rosenbusch, Holmquist and the British School as represented by Teall and Flett for example, use the term as equivalent to dynamic metamorphism ; Harker considers that the essential of regional metamorphism is a conjunction of high temperature and intense shearing stress ; and still others, such as Geikie, Kemp and Clarke, maintain that the definition should state clearly that the transformation was not connected with igneous activity. Daly (1917), who has wrestled valiantly with these matters, approves of this last definition—regional metamorphism is that 'not caused by eruptive bodies,' and its opposite is local metamorphism 'caused by eruptive bodies.' For my purpose here, I propose to take the expression 'regional metamorphism' as meaning only and exactly what it says, namely, a transformation that has affected large portions of the earth's crust.

I have noted in the preceding paragraph the equivalence, according to

Rosenbusch and others, of regional and dynamic metamorphism. Whilst I do not feel so bitter about dynamic metamorphism as Termier did, still I hold that its efficacy as a process of rock-transformation has been exaggerated. As we have seen, the forerunner of the term dynamic metamorphism was Lossen's dislocation-metamorphism, a simple expression denoting a transformation genetically connected with dislocations of the crust. It is true that Lossen demanded that heated water should be active as well, but if we agree, as some (notably van Hise and Riecke) do, that any metamorphism is impossible without the activity of solutions, then Lossen's demand was not unreasonable. Lossen's old term would cover a large class of phenomena, such as the dominantly mechanical breaking-down of rocks, cataclasis, mylonitisation and the like, all connected with demonstrable dislocations. It must be remembered, however, that some authorities, Daly being among them, consider that recrystallisation is essential in all metamorphism, and exclude purely mechanical transformations. I do not sympathise with this exclusion and propose to continue to use dislocation-metamorphism for that class of phenomena I have mentioned.

Rosenbusch, having replaced Lossen's excellent term by his dynamic metamorphism, proceeded to make this the equivalent of regional metamorphism and to regard orogenic pressure as its cause. Backed by the authority of Rosenbusch, dynamic metamorphism became fashionable, the dynamic aspect overshadowed all others and mountain-building movements could do all things requisite and necessary. It must be remembered, however, that Judd, Sederholm and others urged caution and, of course, many of the French were frankly sceptical ; nevertheless, the notion of a metamorphism on a regional scale ' induced in rocks because of their deformation ' remains still a leading principle in many schools of metamorphic geology. Sometimes we have the notion in its purest form. For example, at Flin Flon, Canada, where a progressive metamorphism has achieved garnet, the cause is ascribed by Ambrose to heat developed by shearing.

On the other hand, the emergence of ideas on a static or load metamorphism of regional extent, in which orogenic pressure is not a causal condition, indicates that all is not well with the supposed equivalence of dynamic and regional metamorphisms. Before discussing static metamorphism itself, I propose to deal with some of the difficulties raised by this equivalence. I take as my definition of dynamic metamorphism that given by Daly (1917)—' metamorphism which is induced in rocks because of their deformation, the crustal movement being of the orogenic type' ; it is a division of regional metamorphism since it is ' not caused by eruptive bodies.'

In an earlier part of this Address, where reference is made to the work of Becke, Weinschenk, Sederholm, Milch, Daly and others, I mentioned certain facts commonly observed in regionally metamorphosed rocks but difficult to reconcile with the operation of pressures tangential to the earth's surface. One of the chief of these observations is the coincidence of schistosity and bedding. As metamorphic rocks showing this coincidence are often horizontal over great areas, the notion of static or load metamorphism has been put forward. But, as I have already mentioned, Daly (1917) has cited a score of regions where schistosity and bedding agree—in folded and horizontal rocks alike. These are the phenomena that Daly felt to be ' truly inexplicable

by pure dynamic metamorphism,' an opinion with which I am in complete accord. It is true that some observers have questioned whether the banded appearance of many crystalline schists is to be interpreted as original bedding. For instance, it has been suggested that this banding may be due to flow of softened heterogeneous masses, or to the operation of some kind of differential diffusion whereby different components become lodged preferentially in certain bands. Again, Barth (1936), for example, in his account of the metamorphism of the Palæozoic rocks of Dutchess County, New York, looks with suspicion on the interpretation of layers of different composition in metamorphic rocks as representing original stratification, and prefers to emphasise the importance of shear-planes and subsequent crystallisations along them in the production of schistosity and foliation. While these, and other, explanations of banding may be valid for certain areas, still I believe that schistosity and stratification are coincident in a vast number of cases. My belief is strengthened by the considerations dealt with in the next paragraph.

The preservation of original textures in rocks that have been completely recrystallised is a matter of common observation. There are innumerable examples of the preservation in regionally metamorphosed rocks of minute sedimentation-characters, such as graded bedding, current bedding, the inter-lamination of undisturbed, exceedingly thin, beds, and so forth—characters that should have been obliterated by the action of orogenic pressures. As an instance of how excellent this preservation may be, I may recall the successful use of current bedding and graded bedding by Bailey, McCallien, Read and others in unravelling the stratigraphical sequence in the Grampian Highlands. An additional and telling example is the recognition of varved bedding in the metamorphic rocks of Finland and Canada. It seems to me that such details of original textures cannot possibly be preserved if the rocks in which they occur were metamorphosed ' because of their deformation.' I admit, of course, the operation of dynamic action in the production of various metamorphic rocks of low grade, but in these cases the original primary textures are completely obliterated. Van Hise (1898) emphasised this aspect of dynamic metamorphism and held that complete destruction of original textures will result from comparatively little motion. I may cite from my own experience the entire absence of any sedimentary textures, apart from those afforded by a conglomerate-schist bed, in the Muness Phyllites of Unst in the Shetlands. This obliteration in low-grade metamorphism and preservation in high-grade metamorphism of original textures shake my faith in the unity of the progressive series from the chlorite zone or epizone to zones of higher grade,—but this topic I reserve for a later page. Whether the topic arises at all depends, of course, upon the validity of the argument that the banding of metamorphic rocks represents in most cases an original bedding, and I consider the validity unquestioned.

It may be objected that beds of different competencies will react differently to orogenic stresses, and that, for example, whilst original textures may be preserved in quartzose members they may be destroyed in pelitic rocks. Admittedly some accommodation may take place in the clay layers ; if this is effected during the metamorphic epoch, rotated porphyroblasts may be the result. The Abbildungskristallisation of Sander which we may translate as mimetic crystallisation and describe as a crystallisation in which the original

textures, bedding, etc., are in control of the orientation, is so common a phenomenon that it cannot be disregarded.

Whilst stress is admittedly the dominant factor in the production of low-grade metamorphic rocks, there is agreement that its effect is small in the higher grades, where the products of regional and thermal metamorphisms converge, high temperatures being in control. There is no correspondence (*pace* Ambrose and others) between the degree of deformation and the metamorphic grade, unless it be one of the greater the deformation the lower the grade. In this connection, I may cite the failure of experimental work, like that of Larsen and Bridgman (1938), to produce minerals characteristic of rocks supposedly formed by dynamic metamorphism. Stress, by itself, is not enough.

No one can dispute the observed fact that regionally metamorphosed rocks are often more or less violently folded. The inference so often made that the metamorphism and the folding are coeval is not, however, always justified. It seems to me clear, on the basis of the immediately preceding paragraphs, that most fold-structures in regionally metamorphosed rocks ante-date the crystallisation, this being post-tectonic in the terminology of Sander.

I have dealt here with the contention that deformation causes regional metamorphism. It is necessary to remember that the converse, that regional metamorphism causes deformation, has been held to be true. I can only draw attention to Perrin's (1937) recent discussion of this aspect, and make mention of Mellard Reade's expansion theory of mountain-building and of Bailey Willis's theory of metamorphic orogeny. Reade supposed that heating and metamorphism of the sediments in the deeper parts of the geosynclines gave rise to an expansion which expressed itself in folding and granitisation. This is essentially what was later suggested by Joly. On the other hand, Willis saw in the pressures exerted by the oriented growth of crystals during metamorphism a sufficient cause for orogenic folding.

Even from the foregoing inadequate discussion, it will be realised, I trust, that there are many features of regional metamorphism that are incompatible with dynamic action. The recognition of this has led to the invocation of static or load metamorphism, and I propose now to examine the validity of this notion. First, however, I must quote Daly's definition: 'static metamorphism is that phase of regional metamorphism which is not induced by orogenic deformation'; load-metamorphism is the subdivision of static metamorphism which takes place at high temperatures. Remember that, according to Daly, regional metamorphism is 'not caused by eruptive bodies.

One of the especial difficulties that has to be faced by advocates of a metamorphism due to the vertical pressure of the overlying beds is the existence of completely non-metamorphic rocks which have nevertheless been covered by an immense thickness of superincumbent strata. From the innumerable examples available, I select a few. Chamberlin (1910) estimates that the Palæozoic rocks of Pennsylvania which have been involved in the Appalachian folding have been under a cover of from 4½ to 6 miles in thickness; in spite of this great depth of burial and of the intensity of deformation, they show none of the characters of regional metamorphism. Daly has noted the almost complete absence of recrystallisation in the Lower Cretaceous rocks of British Columbia, though they have been beneath a cover of 8,000 metres of sediment. Larsen reports 50,000 feet of non-metamorphosed sediments in California;

Arnold Heim notes 9 kms. in a Chinese geosyncline ; Schuchert estimates 25 kms. in the Rocky Mountain geosyncline, and O. T. Jones nearly 40,000 feet in the Welsh Lower Palæozoic geosyncline. It is clear that vertical pressure due to load is not a prime cause of regional metamorphism.

This difficulty confronting static metamorphism has been tackled by Daly, who meets it by relaxing the rigidity of the doctrine of uniformitarianism. He admits that, compared with its proposed potency in Pre-Cambrian times, load-metamorphism must have been of relatively little importance in later geological eras. To account for this, he assumes that the earth's thermal gradient was steeper during the formation of the Pre-Cambrian so that regional metamorphism under a moderate cover was possible. He considers that this speculation concerning a hotter surface to the earth is ' no more dangerous than the fashionable explanation of all, or nearly all, regional metamorphism by orogenic movements.' I agree that though uniformitarianism suits the events of the 500 million years of geological history as recorded in the Cambrian and later fossiliferous rocks, it may quite likely not be so valid for the 2,000 million years of Pre-Cambrian time. I am not competent, however, to discuss Daly's speculation, and I have only to state that I feel that the proposal does not strengthen the case for regional static metamorphism.

The idea of a metamorphism controlled by load, as such, fails to meet many other observations. I have space here only to cite the occurrence, in the Eastern United States, of highly metamorphosed stratigraphically younger beds resting naturally on lowly metamorphosed stratigraphically older beds ; of high-grade sillimanite-zone rocks overlying lower-grade rocks as in Sutherland and Norway ; of the passage, in Banffshire, from slates to metamorphosed rocks containing andalusite, garnet, cordierite, sillimanite and staurolite within a half-mile of coast-section ; of a similar narrow restriction in the Barrovian zones as in Dutchess County, New York. In my opinion, the effect of load completely fails to account for these observations. Load, by itself, is not enough.

The literature of regional metamorphism abounds in references to the great depths within the crust at which such metamorphism takes place. These suggestions of great depths, however, carry no kind of conviction to my mind. On the contrary, I consider that high-grade regionally metamorphosed rocks must have been formed in many areas under relatively little cover. Daly was of this opinion too, and he was influenced thereby in his idea that thermal conditions were different in Pre-Cambrian time from what they were in Palæozoic time. He pointed out that from Clarke's data it is possible to form a rough estimate of the total amount of rock eroded in geological time, and that only a small portion of this amount can be assigned to Pre-Cambrian time. Of this small portion, part is represented in the non-metamorphic Pre-Cambrian sediments which lie unconformably on the metamorphosed basement. The several complexes of the basement were highly metamorphic before the denudations corresponding to the unconformities which separate them. From a consideration of these points, and of the great volume of Pre-Cambrian rocks, Daly concludes that the average cover on the complexes at the time of their metamorphism was much less than 5,000 metres in thickness. Barrell (1921) came to a similar conclusion by an argument based upon the amount of salt in the sea and of the erosion of the igneous rocks to give this. He

decided that Pre-Cambrian erosion had removed a cover of less than a mile in thickness.

Though these arguments may not appear altogether sound to some, still I suspect that the notion of the great depths of regional metamorphism flourishes because of the supposed necessity of carrying rocks *down* to be metamorphosed. I suggest, and I develop this suggestion later, that as an alternative we should consider, as Joly also would do, the possibility of bringing the metamorphosing agents *up*.

Following on these remarks on load-metamorphism, I may conveniently here call attention to the recent work of F. E. Suess of Vienna on the relation between regional metamorphism and tectonics. Suess considers that in a typical orogen there are three separate zones—an outermost, the non-loaded, zone of folded non-metamorphic rocks, then an intermediate zone, the loaded zone, where the rocks are violently folded and metamorphosed by the activity of a creative block (the *traîneau écraseur* of Termier). This creative block, which constitutes the third, or innermost, zone, is moved to form the load upon the loaded zone. Examples may make this classification clearer : in the Caledonids of this country, the non-loaded zone is represented by the folded Lower Palæozoic rocks of Wales. the Lake District and the Southern Uplands, the loaded zone by the Dalradian and the creative block by the Moines ; in the Variscan orogeny of Central Europe the creative block of the Moldanubian has given rise to the regional metamorphism of the loaded zone, the Moravian ; in the Alps the load is the Austrids, the loaded zone the Pennids. Two fundamental types of regional metamorphism stand in dependent relation to the tectonics of the creative block, or the load, on the one hand, and of the loaded zone on the other.

The first zone, the load, is characterised by a type or facies of regional metamorphism, styled periplutonic by Suess, which is closely associated with batholithic intrusions and essentially thermal and non-stress in type ; magmatic transfer and solution have led to the formation of katazone rocks with a post-tectonic mimetic crystallisation ; this metamorphism is not controlled by depth. Periplutonic metamorphism has affected very extensive areas lying outside the true orogenic or folded belts of the crust, and its domain passes downwards into the region of migmatisation and anatexis. Along stripes of deformation, the katazone rocks may be degraded to meso- and epi-zone types, whilst adjacent to the major dislocations a thorough reconstruction may take place through a considerable thickness of rock, giving a type of metamorphism which Suess has recently called hypokinematic. Examples of periplutonic metamorphism are provided by the coast region of southern Finland, the Moldanubian and, though not quite typically, by the Moines of Scotland.

The second, or loaded, zone shows a different type of regional metamorphism, named enorogenic, which is controlled essentially by deformation due to the passage over it of the creative block. Because of the load of this block, isotherms rise in the loaded block below, but the metamorphism of this is mainly due to the setting-up of tangential pressures. Rocks characteristic of enorogenic regional metamorphism are meso- and epi-zonal in type, and high-grade rocks which become involved in this metamorphism are degraded to these lower types. The metamorphism is patchy, metamorphic ‘ unconformities ’ are common, and the crystallisation is often paratectonic, that is,

crystallisation and folding are synchronous. During enorogenic metamorphism there is an immense activity of alkaline solutions which, acting along the multitude of shear-planes, lead to the production of much white mica—a sort of widespread shimmer-aggregate formation. Enorogenic regional metamorphism is confined to the orogenic belts, and is exemplified in the Scandinavian Hochgebirge, the Moravian block and in the Dalradian of Scotland.

From Suess's work it appears that two different supplies of heat are to be considered : first, that produced by the damming-back, as it were, of the earth's internal heat by the thickened cover of the load and effective in enorogenic regional metamorphism, and second, that directly transferred by magma and active in periplutonic regional metamorphism.

Suess bases his conclusions on a series of comparative studies of metamorphism and orogeny in numerous areas, many of which he has visited, in Europe and America. I have no space here to enter into even a general discussion of his views. From my personal knowledge it would be no difficult matter to criticise in detail their application to the Moine and Dalradian rocks of Scotland, but such a criticism by itself would be grossly unfair. A proper test of Suess's interpretation as applied to the Scottish Highlands could be based only on an investigation of the natural history—as I have called it elsewhere—of the metamorphic rocks of that area. British geologists have not considered seriously the possibility of polymetamorphism in the Highland rocks, but, faced with Suess's suggestions, they must do so in the future. It is with some such hope that I have devoted these few paragraphs to an account of Suess's work.

Even the inadequate summary here presented serves to indicate why Suess could not regard the epi-, meso- and kata-metamorphisms of Grubenmann and Niggli as forming a continuous series of rock-transformations gradually increasing in grade, nor could he consider the corresponding zones as separable according to depth since they are fundamentally dependent upon the dynamics of different tectonic controls. He concluded, therefore, that there is no regular series of metamorphic zones ; the zones are not particularly connected with one another and can each occur quite independently of the others. In an earlier page of this Address, I have expressed some misgivings of my own on the unity of the progressive series of zones. I propose now to discuss certain aspects of the zonal notion, especially in connection with a depth-control.

I have already noted the development of ideas on depth-zones and, in connection with static and load metamorphism, I have directed attention to difficulties encountered in regarding grade of metamorphism as directly controlled by depth. Admittedly, metamorphism does often increase in grade with depth, but, as I have said in another place, I personally find no difficulty in envisaging a metamorphism which increases laterally or vertically ; I consider depth, as such, not to be a factor in metamorphism and that if we are to retain a zonal notion, then the idea of depth-control must be completely disregarded.

The view that depth and grade are genetically related has played what I fear to be an unfortunate part in the interpretation of many metamorphic terranes. I can here only instance the Grampian Highlands, where, according to Tilley and Miss Elles, the metamorphic zones have been inverted over considerable areas since their formation. This interpretation seems to me to be

based fundamentally on the conclusion that, no matter what may now be the attitude of the zones, they were originally formed with the highest grade at the greatest depth and with an orderly structural succession from high-grade to low-grade zones from the deeper parts upwards. Even if this fundamental postulate be admitted, and I for one refuse to admit it, still I find it difficult to understand how large-scale inversions of metamorphic zones have taken place without the rocks concerned acquiring a new metamorphism due to, and essentially contemporaneous with, the inversion. One might suggest that the portion of the crust showing such phenomena had been inverted as it were on a hinge, but the requisite hinge would be of so gigantic a size that both the crust affected and the suggestion must collapse. Where, as in the North-West Highlands, rocks of various kinds have been involved in relatively small-scale inversions, they show a metamorphism produced during the inversion. I may recall here, too, that T. Vogt in Norway and I in Sutherland have found high-grade rocks resting on lower-grade rocks and have felt content to consider this the position in which they were originally formed.

The relation between the large-scale tectonics and the metamorphic zones in the Highlands is a question which, in the present state of our knowledge, bristles with difficulties. As we have just seen, the Cambridge School consider that the metamorphism is pre-tectonic and that the metamorphic zones can be recumbently folded. On the other hand, Bailey and others regard the metamorphism as partly contemporaneous with the folding. For my part, I suggest, for reasons which will appear later, that the metamorphism may be post-tectonic. Both in the Highlands and elsewhere it seems to me that the isograde lines are independent of both stratigraphical and tectonic arrangements, and I prefer to relate regional metamorphism not to load nor to deformation nor to tectonic or any other depth.

I have at various places in this Address pointed out the destruction of sedimentary structures in low-grade metamorphism and their apparent perfect preservation in high-grade metamorphism. If these are valid observations, then it seems to me that the progressive series from slates to higher-grade rocks must break down or, at least, that high-grade rocks were not necessarily at one stage of their career in the condition represented by the lowest-grade rocks of the zonal series. Low-grade rocks may once have been high-grade, but the reverse is not necessarily true. I cannot admit that such rocks as the high-grade delicately striped hornblende-granulites of Sutherland, which most likely are of sedimentogenous origin, or the metamorphosed varved rocks of Finland, for example, ever passed through a stage in which the dynamic factor was overwhelmingly dominant. Becke's early classification of regionally metamorphosed rocks into the propylitic type and those resembling products of contact-metamorphism or Milch's separation of his dislocation-metamorphism from load-metamorphism may express real differences, and for these classifications, when shorn of their depth or load aspects, I have some sympathy.

Apart from the question of the time-continuity of the progressive series represented by, say, the Barrovian zones, there is the chemical continuity to be considered. How far do the zones of Barrow represent an isochemical series of pelitic rocks? The degree to which such processes as metamorphic differentiation and diffusion have operated obviously affects the compositions of members of the series at any stage. Quartz and quartzo-felspathic segregations

withdraw material from the unit of rock undergoing transformation, and other components indigenous to the rock may migrate from place to place within it. The staurolite-zone of Barrow seems to demand a special chemical composition for its formation, and this composition might be provided either by the original sedimentary composition or by enrichment in iron and alumina through impoverishment in magnesia by metamorphic diffusion. Barth's (1936) interpretation of the extreme composition of the Bamle formation in South Norway by the expression of low-melting components is concerned with a notion similar to that contained in the latter half of the previous sentence. Such possible departures from the isochemical series arise through processes inherent in the rock. There is, however, another aspect of this topic which, though usually ignored in this country, must in my opinion be carefully considered. The possibility of the introduction of material of so-called magmatic origin is one that certainly cannot be dismissed in the higher grades, and one that might apply even to the lower grades of regional metamorphism. The remaining portion of this Address is largely concerned with this possibility. It will be convenient for the development of my argument, however, if we transfer ourselves to the domain of ultra-metamorphism, and I propose first of all to discuss the reality of granitisation, for, if granitisation is real, certain consequences seem to follow.

In a paper which has appeared during the writing of this Address, granitisation is defined by Malcolm MacGregor and Gilbert Wilson (1939) as 'the process by which solid rocks are converted to rocks of granitic character.' It includes all such operations as palingenesis, syntexis, transfusion, permeation, metasomatism, migmatisation, injection, assimilation, contamination, and the like. I have already made mention, in previous pages, of earlier views on this topic in connection with the French School, Termier, Sederholm, Fenner, Hugh Miller, and others. More recent developments have been ably summarised by MacGregor and Wilson. They make reference to the investigations of Goldschmidt in Stavanger, Norway; of Read in Sutherland and Aberdeenshire, Scotland; of Quirke and Collins in Eastern Canada; of G. H. Anderson in the Inyo Mountains of Colorado and Nevada; of Barth in Dutchess County, New York, and of others; they refer, too, to their own work in Scotland and Yugo-Slavia. I mention these authors and localities to show how completely international the idea of granitisation has become. MacGregor and Wilson discuss the chemical data supplied by these investigations, and the trends of the progressive changes in composition as granitisation proceeds. They conclude that exchanges take place between the country-rocks and their pore-fluids—whether these are entirely indigenous or reinforced by accessions from magmatic sources—and that these exchanges are selective so that there is a convergence, both chemical and mineralogical, of rocks originally different. They consider two processes to be concerned in granitisation; first, a metasomatism under the influence of 'permeating highly energised fluids—emanations—ahead of advancing magma,' and second, a mechanical penetration by magma. I consider that no reasonable objection can be raised to these conclusions, notwithstanding the uncompromising attitude of Rosenbusch and others. It seems to me that this Franco-German granitisation war, at least, has been won by the French.

The origin of granitic magma is admittedly a problem closely related to

granitisation, but nevertheless one which does not directly affect the validity of this process. To what extent migma can become magma is a matter for individual judgment. We have truly a varied choice of schemes for the production of granitic magma. We can believe that it exists as a primary earth-magma, or that it can be produced by differentiation from a primary basaltic magma, or by the fusion of the granitic layer of the crust, or by paligenetic melting by basal fusion of sediments involved in regional subsidence, or by solution of the low-melting components of crustal rocks and the expulsion of the solution so formed, or by rheomorphism, that is, the conversion of sedimentary rocks into mobile masses by the action of emanations. We can derive the energising fluids involved in granitisation from a magmatic source and permit them to produce granitised rocks and even new granitic magma ; or we can accept the emanations as available without questioning their ultimate source and see in them the primary agent in the production of magmatic rocks. Whatever mechanism we regard as reasonable, I consider it demonstrated in dozens of localities that 'solid rocks are converted to rocks of granitic character.'

The question of room in migmatisation is one that has caused difficulties to many observers. For example, Milch drew attention to series of sediments which remained the same thickness over considerable areas even though they were said to have been injected by much igneous material ; he preferred to regard the felspathic material seen in such series as arising from the rocks themselves and not contributed from outside. This room-question was answered by Hugh Miller 50 years ago, and has been answered many times since. Replacement is the essential process in the formation of the migmatites. As Hugh Miller said, 'parts of these granites are, in fact, pseudomorphs or granitic casts, preserving within parts of their mass, as replacement structures, the remains of the structures of the pre-existing rocks.' It is unfortunate that the term injection-complex, used in this country, emphasises injection, since permeation, imbibition and metasomatism are more widespread phenomena. As I have pointed out elsewhere, the formation of banded gneisses and lit-par-lit complexes is best explained by a process of replacement to different degrees along layers of different permeabilities. The many examples of the tracing of the regional country-rock structure through granitic masses, the existence of thin plane screens of country-rock in them, the great extension of minute *lits* of quartzo-felspathic material in migmatites, and the detailed heterogeneity of many granites are all readily explicable by a replacement origin for these rocks. Though museum specimens of granites appear homogeneous, they are far from this in mass ; not the least important function of public houses, banks and other opulent edifices, is to display large polished slabs so that geologists can satisfy themselves of this fact. Many demonstrations of the replacement origin of granites and granitic migmatites are available ; I need only cite as examples the Cassia batholith of Idaho which, according to G. H. Anderson, has become three times as large by replacement of its bordering country-rocks ; or the beautiful replacement phenomena seen in the Southern Greenland rapakiwi granite described by Wegmann. In the case of the Dartmoor granite, Brammall considers that the aureole has lost a contact-metamorphic zone of higher grade.

Replacement in sedimentary rocks will be controlled by the original

structures of such rocks. Permeation by the emanations or ichors will take place preferentially along certain layers depending upon both the chemical and physical nature of these layers. Original platy minerals lying in the bedding planes will become enlarged if they suit the new chemical environment and new-formed minerals will grow so that their direction of greatest crystallisation-velocity agrees with the old planes of weakness. The original sedimentary structure may thus become preserved until a high degree of granitisation has been reached and the bulk-composition of the rock has been greatly changed. I consider the foliation of granitic gneisses, for example, as essentially controlled by previously existing sedimentary structures, and not by any process of dynamic metamorphism or piezo-crystallisation.

Whether the granitising solutions are thought of as emanations of no specified ancestry, or as ichors from a granitic magma-body, opinion is agreed amongst workers in this subject that they are highly mobile and capable of great chemical action. Working in conjunction with the pore-fluids of the country-rock, they can transform vast portions of the crust. Nockolds, dealing with the contamination of granite magmas, has concluded that the volatiles there concerned form a medium of low viscosity in which diffusion of the reactive materials can take place with comparative freedom. Fenner and others have emphasised the importance of gas-activity in granitisation. Emanations of this type, derived from a granitic hearth, move into the walls and, since they carry great supplies of heat, are able to travel long distances. Even when the activity of one particular batch declines, new accessions of heat arrive from the magma and continue the work. The classic views put forward by Lacroix regarding the efficacy of reactive volatiles must not be overlooked. Gases are able to penetrate where liquids could not. Fenner points out that in this gaseous transfer there is a strong tendency to reproduce in the contact-rocks the same minerals that are crystallising from the magma. In connection with direct granitic invasion, therefore, gases may be of great importance; when they have condensed to solutions and have received assistance from the true liquid residuals and from the pore-solutions, they must be capable of gigantic results.

I have mentioned, in a previous paragraph, Milch's preference in considering that the felspars in rocks believed to have been granitised had been derived from the rocks themselves rather than from outside sources. This objection to felspathisation by the metasomatic action of introduced materials has been raised by Harker, Thomas and Campbell Smith, and others in Britain. I agree that at certain stages of thermal metamorphism without transfer of material felspars are formed, but such occurrences are not like those of the 'augen-gneisses' and porphyroblast-schists of the great migmatite areas. In felspathisation, material for the formation of felspar may be contributed by both the country-rock and the pervasive introduced solutions. There is an abundance of both field and chemical evidence which demonstrates the validity of felspathisation. One of the neatest unequivocal cases is provided by Miss Reynolds in her account of the felspathisation of quartzite xenoliths in the Colonsay hornblendite. Malcolm MacGregor and Gilbert Wilson have recently dealt with some of the chemical data available, drawing this from such diverse fields as Stavanger, Sutherland, Nevada, Lake Huron, Yugo-Slavia and Galloway. The field-evidence is especially strong. Beginning with the

classic observations of the French school, especially Barrois's beautiful felspar trails at the contacts of the Rostrenon granite, and remembering Grenville Cole's statement that in Donegal 'the schists become porphyritically set with the constituents of the granite,' we pass on to a multitude of modern observations showing the validity of felspathisation. I list but a few of these in order to bring the weight of the evidence home to the British ; Grout (1937) has listed a dozen examples ; and we have in addition the observations of Agar, Barbour and Fettke in the Eastern States, Goodspeed at Cornucopia and Anderson at Inyo in the Western States, Goldschmidt at Stavanger, Read in Aberdeenshire and Sutherland, Du Reitz in Sweden, Wegmann in Greenland, Kranck in Finland, Barth in Norway, Barth in New York, Turner in New Zealand, Alderman in Australia, many examples from the Alps, and dozens elsewhere. The progress of felspathisation produces porphyritic gneisses and granites without the aid of dynamic metamorphism. Further, unless we assume the possibility that minutely identical felspars can form in two quite different environments, namely, those of a granitic melt and of a solid country-rock, then the replacement-origin of such granites as those of Shap, Skaw (Unst), and some rapakiwis must be considered as reasonable. But these are topics rather outside my text. All I wish to emphasise here is that granitisation and felspathisation are valid processes and that they are essentially based upon replacement.

In regions of granitisation there has been an afflux of material, either from a 'magmatic' body or from some unspecified source. It is reasonable to believe that during the resulting replacement there occurs an emigration of material. Holmes (1937) has put the whole matter graphically—'the "granite" is the balance of what was there originally, *plus* what has migrated in, *minus* what has been driven out.' The emigrating material moves into the country-rocks adjacent to the theatre of granitisation.

The material thus moving through the country-rocks is of several origins and qualities. It consists of (i) the material expelled from the region of granitisation, (ii) the direct emanations from the granitising agent, and (iii) the pore-fluids of the country-rocks. Its diverse constituents must move with different speeds, perhaps depending, as Backlund has ingeniously suggested, upon the ionic radii of the participating elements. Various overlapping belts of precipitation may come into being, and from each a further expulsion may take place. By some such processes zones of various characters arise about the granitisation or migmatite core. What seem to be special examples of the operation of this mechanism are provided by the following mainly Scandinavian observations.

Magnusson (1936) has deduced at Kantorp, Sweden, what I may call a precipitation-front of aluminium, iron and magnesia-rich material and a corresponding removal-front of silica, alkalies and lime ; the same observer (1937) has interpreted the cordierite-rich Södermanland gneisses as due to a regional magnesia metasomatism connected with the Malingsbo granite. Barth (1938) has described a regional soda-metasomatism in the sparagmites of South Norway, these showing an increase of soda and alumina from an original sandstone to a granulitic gneiss. We may recall too Eskola's (1914) classic work on the Orijärvi area of Finland, where metasomatic replacement of lime and alkalies by iron oxides and magnesia is demonstrated. Wegmann

has elaborated a magnesia-metasomatism dependent upon the expulsion mechanism in granitisation ; he expects to find a zone characterised by cordierite in close proximity to the migmatite area, whilst farther away would be found lower-temperature minerals like andalusite, kyanite, garnet, etc., and farther still tourmaline. The formation of ' fronts ' of more or less marked chemical individuality can be exemplified by the soda-fronts of Stavanger, Sutherland, and Cromar, Aberdeenshire, by the potash-front of Hango, Finland, and by the magnesia-front of Orijärvi ; there is no need to elaborate these examples.

From the reference I have just made to Wegmann's views, it is clear that he, with many others, considers the domain of regional metamorphism to be transitional to and genetically connected with the domain of migmatisation. I can recall now Termier's saying—no one could reasonably doubt that in the formation of the true crystalline schists there had been an afflux of elements from the depths which had chased the old elements before them. I may recall, too, references I have made in the earlier part of this Address to the opinions of Michel-Lévy, Weinschenk, Koenigsberger, Sederholm, Adams, Barrow and others on the genetic connection between regional metamorphism and granitic intrusion. Before I deal with this final topic, however, it is almost necessary, in view of what I have said in the last few pages, to re-define the title of this Address. Igneous action, according to some, may not be concerned in migmatisation. As I do not propose to examine here what igneous connotes, I now limit my subject at this late stage to that of the relation between regional metamorphism and migmatisation.

One of the most firmly established facts of metamorphic geology is the close association in the field of highest grade metamorphic rocks and migmatites. I could cite dozens of examples of rocks containing sillimanite and cordierite which occur as more or less discrete portions of migmatitic complexes. I content myself with the mention from our own country of Barrow's sillimanite-zone itself in Aberdeenshire, of the cordierite-sillimanite-gneisses of Buchan, and of the sillimanite-gneisses of the injection-complexes of Sutherland and Morar, and of Anglesey—all these high-grade rocks are in or adjacent to areas of migmatisation.

The significance of this coincidence has been differently interpreted. Termier, as we have seen, considered that regional metamorphism and igneous activity were two effects of the same cause, the rise of the *colonnes filtrantes*—the emanations of to-day ; the igneous magmas were generated in place. Harker and most British geologists regard igneous intrusion in the sillimanite-zone as an incident in the rise of the isotherms in that region. This rise is a direct invasion of the earth's internal heat, and any solutions concerned in regional metamorphism are for the most part not of magmatic origin. As we have already noted, Barrow considered his zones to be in the nature of gigantic thermal aureoles around intrusions of the Older Granite. Barrow's view is that generally accepted by students of migmatisation—it is inherent in the interpretations of migmatisation and granitisation advanced by the Scandinavians, the French and many Americans. I prefer it myself on various grounds. The postulated rise of the isotherms seems a more mysterious process than the bringing-in of heat by magma or emanations ; vast supplies of heat and material are necessary in the granitisation process and the higher

grades of regional metamorphism, and both can be supplied by igneous invasions. Further, there are cases of migmatites and rocks of the sillimanite-zone formed above lower-grade rocks—emanations or magma can be injected in such a position, but hardly the isotherms. On these and other counts, I adopt the view of the company familiar with migmatites and see with them a direct causal relation between the highest grade of regional metamorphism and migmatisation.

In my opinion, therefore, the cordierite and sillimanite zones are genetically related to granitisation. But these zones are the final stages of the apparently continuous progressive series of Barrovian zones which as a whole supply the common types of regionally metamorphosed rocks. Any departure from isochemical conditions in this series, such as I have suggested in a previous page, may arise through the operation of the advancing fronts of various metasomatisms. I may here call attention to the data, assembled by Brammall, showing that soda increases relatively to potash in the series shale, phyllite, mica-schist, and to comparable observations at many granitisation margins. An excellent case is that described by Gilbert Wilson from Kapaonik, Yugoslavia. Further, argillaceous rocks when involved in contact metamorphism show a change in composition ; the rocks adjacent to enormous granitisation regions must be more vitally changed. The physical reality of the series of progressive zones is based upon a considerable number of observations in all parts of the world. I need only refer to the work of Barrow, Barth, Balk, Billings, Goldschmidt, T. Vogt, Tilley, Du Reitz, for examples. It seems reasonable to me, therefore, to believe that regional metamorphism as a whole is genetically related to 'igneous' activity of some kind. This is no new belief; it dates from the beginning of our science, and has been held by many, as I have already recorded. A stimulating expression of it was given by Barrell in 1921, and it is inherent in the work of Wegmann and many others.

Out from the central theatre of granitisation there pass waves of metasomatising solutions, changing in composition and in temperature as they become more distant from the core and promoting thereby the formation of zones of metamorphism about it. Very often a spurious depth control appears to have operated, since the flow of solutions must be largely towards higher parts of the crust. Such a metasomatic metamorphism accounts for the superposition occasionally observed of high-grade zones on lower-grade, and does away with the infelicities attending the alleged inversion of metamorphic zones. Further, the difficulties that the idea of static or load metamorphism fails to meet are surmounted. Deeply buried sediments remain unmetamorphosed unless igneous material gets access to them. In metasomatic metamorphism, original sedimentary textures can be reasonably preserved, mimetic crystallisation can prevail, schistosity and bedding, even in violently folded strata, can coincide. Finally, all those phenomena which Daly felt to be 'truly inexplicable by pure dynamic metamorphism' are satisfactorily explained.

A continuous series of changes in composition from low-grade regionally metamorphosed rocks to migmatites has been established by many investigations. I need only recall those of Goldschmidt at Stavanger and of Barth and Balk in Dutchess County, New York, as examples. Even in the low-grade rocks changes are perceptible and all must be ascribed to the activity of material from a granitisation centre. To move this material and to promote

the recrystallisations and replacements that occur in cubic miles of rock, great quantities of solvents are required. It seems to me unlikely that the solvents in action are indigenous to the country-rocks—they are more reasonably to be derived from a granitic source. The investigations of Goranson (1931) on the solubility of water in granite magma and the discussion of the problem by Gilluly (1937) indicate that granite magmas may contain possibly 8 per cent. of water. When the enormous extent of migmatite granites is considered, it is clear that sufficient water is available to promote the changes seen in the regionally metamorphosed rocks.

Are there any indications in low- to medium-grade rocks, not visibly associated with igneous activity in the field, which point to solutions from magmatic sources having travelled so far from the locus of migmatisation? In my opinion, we see such indications in the presence of tourmaline in rocks of all grades. Admittedly, this opinion is one not generally accepted in this country. Goldschmidt and others have shown that argillaceous sediments contain an original boron content, and on this account Tilley, for example, suggests that the tourmaline of the regionally metamorphosed rocks is of this derivation. Others, such as J. F. N. Green and McCallien, interpret the tourmaline as due to the recrystallisation of detrital tourmaline deposited with the original sediment. These are pertinent objections, but on balance I prefer to regard most tourmaline in metamorphic rocks as due to impregnations from granitisation fluids. Tourmaline occurs not only in pelitic derivatives but in rocks of other compositions. In many examples of high and medium grade rocks it is clearly introduced, as shown by its relation to the other minerals present. Williamson in Glen Shee, Billings in New Hampshire, Emmons and Calkin at Philipsburg, Turner in New Zealand, and a score of others, have contributed observations agreeing with this conclusion. Further, Turner, and Barth in New York State, for example, have noted the abundance of tourmaline in low-grade rocks, and have naturally extended the zone of penetration of boron vapours into such rocks from rocks of higher grade. I believe, therefore, that the ubiquitous tourmaline in regionally metamorphosed rocks is an indicator of the action of ' emanations ' throughout all grades.

Whilst I have belittled the rôle of the dynamic factor in regional metamorphism, it is of course true that in the lower grades it must be of considerable importance. How can this be reconciled with the view that migmatisation is the prime cause of regional metamorphism? The reconcilation may be sought, I suggest, in the stresses set up by the increase of volume consequent upon the invasion of the crust by the migmatite front. Relief is obtained in the outer and cooler zones by shearing ; in the inner and hotter zones by internal reconstructions. The unity of the zonal series may thus be preserved.

My last topic deals with Barth's recent four-fold classification of all rocks into sedimentary, igneous (e.g. basalt), metamorphic and migmatitic. Metamorphic rocks are those which have been recrystallised without essential anatectic or metasomatic alteration, and are typified by hornfelses. Migmatitic rocks are formed by the stewing of previously solidified rocks in liquids of magmatic or palingenetic origin. Barth would consider metamorphism as a metabolism of rock whilst migmatisation is a metasomatism. Whether we accept this narrow definition of metamorphism or not depends on our ability to decide how much accession of material has taken place in any given rock.

Hornfelses, Barth's typical metamorphic rocks, show, as Brammall, Gilbert Wilson and others have demonstrated, marked changes in composition during metamorphism. I feel that Barth's classification obscures the essential unity of regional metamorphism and migmatisation.

I have now come to the end of these somewhat lengthy remarks. I have shown my predilection for dividing all rock transformations into two groups, one those of dislocation-metamorphism associated with dislocations of the crust, and the other those of regional and thermal metamorphism, associated with igneous activity. My remarks, I trust, will receive thorough criticism. I am prepared for this, for, just as things too absurd to be said can yet be sung with perfect propriety, so views too tenuous, unsubstantiated and generalised for ordinary scientific papers can yet appear with some measure of dignity in presidential addresses.

SECTION C.—GEOLOGY

COMMUNICATIONS

Prof. D. E. Innes.—The geology of the Dundee district.[1]

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Prof. W. T. Gordon.—A new Carboniferous seed-type from Tantallon, North Berwick.

Ashes at Oxroad Bay yielded 8 specimens of a new seed, radiospermic, some 50 mm. long and 6 mm. broad. The stalk, tapering to 1 mm. diameter, is gutter-shaped, with horse-shoe-shaped bundle dividing, upwards, into 5 or 6 mesarch strands symmetrically disposed round the seed axis. Stiff hairs, 3 mm. long, set 10 deep and probably separated and surrounded by mucilage, invest the seed-base.

The integument, basally, has an inner zone of parenchyma, mucilage cells and scattered fibres, and an outer zone with plates of fibrous mechanical tissue interspersed with parenchyma. A sub-epidermal pallisade layer abuts on the ill-preserved hairy epidermis.

At the nucellar-base, some 12 mm. above seed-base, the diameter is 4·5 mm. Here the integumental tissues have segregated into 5 or 6 valves, convex outwards, spaced by deep, longitudinal grooves, and organically continuous with the nucellus. This domed nucellus, 11 mm. high, is capped by a semi-spherical pollen chamber, 1 mm. high, with apex centrally depressed. From the base of the depression arises a tube or *salpinx*, 5 mm. in height.

The integumental valves now separate from the nucellar apex, continue as 5 or 6 finger-like processes, some 22 mm. long, and taper to blunt rounded tips. Basally the interior surfaces of these processes bear long, downy hairs intertwined to a felt-work supporting the *salpinx*.

This seed, specialised for semi-arid conditions, must be assumed efficient, and pollination mechanism, accordant with structure and environment, is suggested.

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[1] Professor Innes' chapter on this subject in the *Scientific Survey of Dundee and District* appeared in the previous issue of *The Advancement of Science*, Supplement, p. 10, *seqq.*

Dr. J. Pringle.—The discovery of Cambrian Trilobites in the Highland Border rocks near Callander, Perthshire.

During a recent investigation of the Kilmahog Limestone and associated strata in the Callander district, it has been found that the limestone is faulted against a series of graphitic shales in the Leny old lime quarry, and not interbedded in them as formerly supposed. Moreover, in these graphitic shales are several bands of a greyish-black limestone, which contain a few thin fossiliferous layers yielding Cambrian trilobites. A collection of these fossils has been submitted to Dr. C. J. Stubblefield for examination, and he refers the majority of the specimens to a new species of *Pagetia*. He reports that this Cambrian genus is almost entirely confined to Middle Cambrian strata, and has not been recorded from younger rocks. The inference therefore is drawn that these grey-black limestones are probably of Middle Cambrian age.

Further work is now being carried out with the aid of a grant from the Royal Society, and much of it will be devoted to the Kilmahog Limestone and its suggested equivalent—the Aberfoyle Limestone—in the Margie Series at Aberfoyle. In lithology these limestones are almost identical, but it is by no means proved that they are of the same age. The discovery of certain trilobite fragments in the Aberfoyle Limestone in 1938 revives the hope embodied in the suggestion made by Prof. T. J. Jehu and Dr. R. Campbell that further search of this limestone might result in finding fossils additional to those they had described from the bed.

Dr. J. Pringle and Dr. M. Macgregor.—The Carboniferous rocks at Bridge of Awe, Argyllshire.

The existence of the small outlier of sedimentary rocks at the western end of the Pass of Brander was first noticed by Macculloch in 1817. The sediments are of littoral facies and the reddish colour of many of the beds, coupled with the fact that they outcrop in the midst of lavas of Lower Old Red Sandstone age, led observers to regard them as belonging to the same formation. This view held up to 1897, but in the following year Mr. D. Tait discovered a few plant-remains in shales a little north of Bridge of Awe and as a result of his work the beds were referred to the Carboniferous and tentatively placed in the Calciferous Sandstone Series.

Recent investigations by the authors have shown that the Carboniferous rocks occupy a larger area than was formerly supposed, about two-thirds of a mile in length and approximately a quarter of a mile in width. A new plant-bed has been located on the south side of the bridge which has yielded specimens of *Asterocalamites* and one or two forms described by Dr. R. Crookall as very like *Rhacopteris petiolata* (Goepp.). The plant evidence is not decisive but suggests a Lower Carboniferous age for the sediments. No animal remains have been obtained, the previous record of *Modiola macadami* being undoubtedly an error. The paper describes the sections that are available for examination and points out that lithologically the strata resemble these in the lower part of the Carboniferous succession at Inninmore on the Sound of Mull.

Dr. Emily Dix and Mr. W. D. Ware.—The occurrence of the Similis-Pulchra Zone in the Pembrokeshire coalfield.

In this coalfield the strata are extraordinarily disturbed, so that considerable difficulty is encountered in reconstructing the details of the sequence, especially on lithological data. Trueman and George (1925) recorded the *ovalis* and *modiolaris* zones in the east of the coalfield, while Trueman (1934) indicated the presence of the *phillipsi* and *tenuis* zones in the western part. One of the writers (E. D. 1933)

pointed out on palæobotanical evidence that Goode (1913) erroneously concluded that the equivalents of the Millstone Grit and the Lower Coal Measures of Yorkshire and of the Pennant Series in South Wales were missing in Pembrokeshire.

In the area south of Haverfordwest it can be shown that both the *lenisulcata* and *similis-pulchra* zones occur. The dividing line between the Coal Measures and the Millstone Grit was drawn (1914) at a lower horizon than in the main basin of the South Wales Coalfield, namely, at the top of the sandstone succeeding the *Gastrioceras cancellatum* beds. In the measures above the true Farewell Rock is a remarkable persistent *Lingula* bed, beneath which non-marine shells of the *lenisulcata* zone occur.

O. T. Jones recorded a marine bed near Picton Point (1914), and he referred it to the 'Lower Coal Measures.' Floras and non-marine faunas, found in association with the marine bed, indicate that these rocks should be included in the *similis-pulchra* zone, while the marine bed is the equivalent of the Cefn Coed Marine Bed. No trace of the *ovalis* and *modiolaris* zones has been found in this area and various reasons are postulated for their absence, including a possible unconformity with overstep.

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Dr. Emily Dix.—Some interesting sections in the Warwickshire coalfield.

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Dr. A. Lamont.—Antidunes in geology.

During his work on the transport of débris by running water, W. K. Gilbert investigated antidune ripple-crests in sand which rush back against the direction of flow, erosion taking place on the concave sides and deposition on the convex. Though a geologist, Gilbert did not realise that these ephemera might be preserved in certain rocks. Nevertheless, when he published, antidunes had already been figured by Sorby from the green slates of Langdale, Lake District.

Since then examples have been found by Hartley in sediments of the Borrowdale Volcanic Series (? Llandeilo), by Whittington in the Cwm Clwyd Ash (Caradocian), Montgomeryshire, by Henderson in the Ardwell Flags (Caradocian), Girvan, and by Benson in the Middle Devonian geosyncline of New South Wales. The speaker adds the following: Carrigaghalia Series (? Caradocian), Doneraile Cove, County Waterford; Ashy Greywackes (? Caradocian), Ballymoney, County Wexford; Plantinhead flags (Caradocian), Trochraigue, Girvan; Rush graded grits and conglomerates (C_{1-2}), Posidonia limestones (D_1–P_1), and Loughshinny shales (P_2), County Dublin.

The antidunes prove the existence of currents, swifter than a critical velocity beyond which turbulence set in, on the slopes of geosynclines and gulfs. The currents may have been of seismic origin.

* * *

Dr. M. Macgregor.—The buried channel of the Forth.

One of the striking features in the geology of the Tay, Forth and Clyde valleys is the existence of buried channels marking the pre-Glacial courses of the principal streams. These old channels are deeper—often considerably so—than the existing ones, and for this reason may be a serious menace in mining operations. Accordingly the collection and correlation of all available data bearing on this subject has an important economic aspect. The late Dr. H. M. Cadell in *The Story of the Firth* (1913) summarised the evidence then available in regard to the pre-Glacial Forth. The present communication deals briefly with boring and mining data collected in recent years. The most striking of these are the results obtained in undersea workings at Bridgeness in 1936. Here, during the driving of a cross-cut mine, loose detrital material was encountered at a depth of 675 ft. below O.D. This material was of a gravelly nature, consisting of small to large pebbles of various rocks, including a

considerable proportion of far-travelled material ; some of the stones were definitely striated. The great depth of the channel at this point suggests local over-deepening by glacial action.

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Prof. J. Ritchie and Dr. M. Macgregor.—Late Glacial remains of reindeer in the Glasgow district.

The bones referred to below were discovered by workmen during the driving of a sewerage extension tunnel across Cathcart Road from Queen's Drive on the south side of Glasgow. They were found in a bed of dark sandy gravel underlying laminated clays and sands of 100-Ft. Beach times. The gravel may be regarded as having been deposited at an early stage of the late-Glacial submergence. The evidence regarding the age of this bed is fully discussed in the paper.

The fragments of bone obtained fit together to form the greater part of the right radius and ulna of a reindeer. The bones are well preserved, with a hard polished surface and sharp splintery fractures ; they show that the animal was adult but of small size. There are no indications of markings suggestive of ice action, and the only artificial surface markings are some slight scratches which have probably been made by the teeth of a small animal. Comparison of the fragments was made with a corresponding bone of a reindeer found in a rock-fissure in the Pentland Hills.

* * *

Discussion on The raised beaches of the Forth and Tay.

Dr. J. B. Simpson.

Following upon the retreat of the last great ice-sheet from the Midland Valley of Scotland the succession of events in the Forth and Tay areas may be summarised as follows : (1) *Pari passu* an incursion of the sea, the late-glacial or arctic sea ; (2) the accumulation of a deposit in this sea, mainly clay and silt, frequently varved, and containing a fauna of arctic character ; (3) a movement of elevation of the land resulting in uplift of these deposits to a height of 130 ft. O.D.—100-Ft. Raised Beach ; (4) in the initial stage (first 50 ft.) of uplift (3) significant readvances of the ice in the upper Forth valley (and elsewhere), moraines deposited down to 65 ft. O.D., and, *probably at this time*, the formation in the seaward parts of the firths of beaches at 60–75 ft. O.D. ; (5) towards the end of the uplift a sea-level *lower* than at present, an amelioration of the climate from arctic to temperate, the establishment of woodland and the formation of peat beds—the Forest Period ; (6) a (eustatic) rise of sea-level resulting in a widespread transgression of the sea and the submergence of the forests beneath marine deposits bearing a temperate fauna ; (7) continued elevation of the land, in greater degree westward, eventually resulting in the emergence of the marine deposits of (6) as a beach (25-Ft. Raised Beach) and of the submerged forest bed.

Dr. E. M. Anderson.

This communication refers especially to the identification of the Carse clays which border the upper portions of the estuaries of the Forth and Tay. These form level plains, at heights increasing gradually, in each case, from about 40 ft. to about 50 ft. above sea-level. They have sometimes been referred to the period of the '50-Ft. Beach,' and sometimes to that of the later '25-Ft. Beach.' The southern margin of the Carse of Forth is a bluff eroded in the main out of loose material, such as earlier raised beach deposits. This feature is in direct continuity with the margin of the '25-Ft. Beach,' which forms a similar cliff, and extends down the estuary. There is therefore little doubt that the formation of the Carse and of the '25-Ft. Beach' was contemporaneous. There is evidence to the same effect with regard

to the Carse of Tay, and the conclusions are borne out, to some extent, by the pollen analyses of Erdtmann. He investigated peats lying above and below the carse deposits, and deduced that the clays themselves must belong to the Atlantic period. The Atlantic age of the '25-Ft. Beaches' of Scotland and Ireland is generally admitted.

Dr. M. Macgregor.

While the main events in the post-Glacial history of the region are well established, there are gaps in our knowledge of the detailed succession to which attention may be drawn. The intermediate beach features which occur locally on the coasts at heights of 60 to 75 ft. probably represent temporary halts in the fall of sea-level that took place at the close of 100-Ft. Beach times. Not much is known of their deposits, however, and it would be of great interest to ascertain if these yield anywhere definite evidence of an amelioration of climate. There is also much work to be done on the sand and gravel deposits which fringe the inner margin of the 100-Ft. Beach. These represent outwash material laid down near the margins of retreating glacier ice and frequently show the hummocky kettle-hole topography characteristic of such deposits. They differ, however, somewhat in age ; some of them, at lower levels, have been apparently planed to a more or less level surface by the action of the 100-Ft. sea, while in other cases there is evidence that they continued to form throughout 100-Ft. Beach times. Any attempt to reconstitute the physiography of 100-Ft. Beach times must also take into consideration the question of assigning some of the high-level terraces along the rivers to the same period. There would seem to be an opportunity for detailed research along such lines.

Dr. R. Campbell.

Although the late-glacial age of the deposits of the 100-Ft. beach is well established, much detailed work remains to be done in correlating these deposits with the moraines and outwash gravels belonging to the last readvance of the ice in north-eastern Scotland. Re-examination of the 'shelly arctic clays' of the Forth and Tay areas is desirable, since, particularly in the case of poor exposures, the clays of the 100-Ft. beach sea may be confused with the shelly boulder clays of the earliest glaciation of the region.

So far as the problems of the post-glacial raised beaches are concerned research along the following lines may be suggested : (1) More accurate determination of the changing levels of the various beaches ; (2) more thorough investigation of the fossil-content of the beaches ; and (3) investigation of the associated forest- and peat-beds primarily to settle the question of whether they all belong to one period.

Mr. C. F. Davidson.

The raised beaches of the Tay region are seldom fossiliferous, and information concerning their climatic equivalent is most readily obtainable from the contemporaneous off-shore and estuarine clays. Locally the 100-Ft. Beach appears to be overlain by outwash sands and gravels, though the extensive fluvioglacial deposits between Wormit and Leuchars were deposited prior to 100-Ft. Beach times. Estuarine clays of 100-Ft. Beach Age, excavated at Errol and Montrose, possess an intensely arctic fauna, characterised by the molluscs *Chlamys groenlandica* (Sow.) and *Saxicava arctica* (Linné), and the foraminifer *Elphidium arcticum* (Parker and Jones). These clays are in part contemporaneous with the late-Glacial readvance of the ice described by Simpson. The well-developed raised beach at 50–60 ft. O.D. is seen at Barry to overlie arctic clays with similar fauna, and is represented in the Carse of Gowrie by clays of boreal to temperate climate in which *Ostrea edulis* (Linné) makes an appearance. It is doubtful if the Tay Forest Bed is of one definite horizon : two or more peat beds have been recorded from various localities (e.g. at Dundee

Post Office), and the peat may have been formed in parts of the estuary cut off from the waters of the firth by a sandspit or similar barrier, as at Kinfauns to-day. The 25-Ft. Beach, with estuarine equivalents (Carse clays) rising somewhat above this altitude, has a fauna approximating to that of present times. Investigation of the tide records of Dundee Harbour over the last century show that the land is now stationary. Rapid coastal erosion is taking place in the Buddon Ness area.

Mr. F. W. Anderson.

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Dr. T. S. Westoll.—The fossil fishes of the 'Caledonian' Old Red Sandstone.

The Lower Old Red Sandstone fishes of the 'Caledonian' region are of great morphological and stratigraphical importance. They include Agnatha (Anaspida; Heterostraci, e.g. Coelolepids and Pteraspidomorphs; Osteostraci, e.g. Cephalaspids) and numerous Acanthodians. True Elasmobranchs, Placoderms and bony 'teleostome' fishes are conspicuously rare or absent.

Morphological Importance.—Stensiö (1927, etc.) showed that Cephalaspids and their allies were jawless creatures, with functional gill-pouches in front of the equivalent of the mandibular arch of living higher vertebrates; this is an important contribution to the theory of the vertebrate head. The loss of the anterior gill-diverticula in progressive vertebrates is related to development of jaws. Watson has shown that the Acanthodians represent an intermediate stage of evolution, with a complete gill-slit in front of the hyoid arch, and has used this evidence in a new classification of the primitive fishes. The Agnatha and Acanthodians provide important evidence of the nature of the vertebrate paired limbs.

Stratigraphical Importance.—Fishes are found in Lower Old Red Sandstone (including Downtonian) of Britain, Spitzbergen, Eastern Canada, etc., and sparsely in equivalent near-shore marine sediments in Europe. Certain peculiarities in distribution (e.g. scarcity or absence of Arthrodires in Scotland) may be regarded as controlled by ecological factors, sometimes indicated in the nature of the sediments. Nevertheless, the fish-faunas allow a satisfactory broad correlation to be attempted.

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Discussion on The boundary between the Old Red Sandstone and the Carboniferous.

Dr. M. Macgregor.

In the Midland Valley of Scotland the strata referred on the one hand to the Upper Old Red Sandstone and on the other to the Cementstone Group at the base of the Carboniferous form a conformable succession, and may be regarded as marking the initial stages in a major sedimentary cycle. The two series were deposited under different physiographic and climatic conditions and the rock-types characteristic of each are in general quite distinct. Recent work in several areas has, however, emphasised the difficulties of finding a definite stratigraphical boundary line and the problem is certainly an important one to the field geologist who has to construct detailed maps. The change in sedimentary facies indicates a transition from one set of climatic conditions to another and this transition was not accomplished or the new conditions stabilised everywhere at the same time. Lithological criteria accordingly do not provide decisive evidence of contemporaneity. Palæontological considerations, again, appear to offer, on the information so far available, no conclusive answer to the problem. The occurrence in the Edinburgh district of plant remains of Lower Carboniferous type in strata which on lithological grounds would be assigned to the Upper Old Red Sandstone may be cited as an illustration. The present communication deals briefly with the historical aspects of the problem and with the general tectonic, lithological and palæontological considerations involved.

Dr. W. Q. Kennedy.

Within the Midland Valley of Scotland, the lithological boundary between sediments of Upper Old Red Sandstone type on the one hand, and those characteristic of the Cementstone Group of the Carboniferous on the other, does not appear to represent a true time horizon, but varies in position from district to district according to the local physiographic conditions which accompanied deposition. If, according to the accepted convention, the base of the Carboniferous is drawn at the lowest *shale-cementstone* horizon, the Cementstone Group, particularly in the West of Scotland, is frequently found to include strata which, on purely lithological grounds, would be assigned without hesitation to the Upper Old Red Sandstone. The two series are therefore regarded as distinct sedimentary facies, and it is concluded that no age significance can be based on their lithological characters.

Prof. G. Hickling, F.R.S.

Prof. T. N. George.

The South-Western Province.—In southern Pembrokeshire and in Devon and Cornwall the Carboniferous rocks (Lower Limestone Shales and Upper Pilton Beds) rest conformably on marine Upper Devonian (Famennian) rocks, and the two formations are generally similar in lithology and in possessing a rich brachiopod-lamellibranch fauna. There is then no very obvious intra-formational junction between the Lower Pilton Beds and the Skrinkle Sandstones on the one hand, and the Upper Pilton Beds and the Lower Limestone Shales on the other.

Elsewhere in the South-Western Province, in the Mendips, the Forest of Dean, Glamorgan, and Breconshire, no marine Devonian sediments occur, and there is a great and very abrupt change from the continental red coarsely-terrigenous unfossiliferous beds of the Upper Old Red Sandstone to the marine shalet and limestones of the Lower Avonian. Westwards, along the northern outcrops in Carmarthenshire and Pembrokeshire, the relation between the two formations is one of unconformity : in this ground, however, the Upper Old Red Sandstone was probably never deposited, and the break is probably not attributable to early Hercynian (Bretonic) movements. From Pembrokeshire to the Mendips the major marine transgression occurred in post-Famennian times (though it was preceded by a Famennian transgression), and the basal beds of the Lower Limestone Shales generally contain an Etroeungtian fauna with *Avonia*, *Productella*, and characteristic lamellibranchs. The Devonian-Carboniferous boundary is conveniently located at this stratigraphical break.

Prof. W. T. Gordon.

Excluding marine algæ, two major breaks occur in the sequence of upper palæozoic plants, one above the Middle Old Red Sandstone and another above Lower Carboniferous beds. Between these limits a bipartite (upland and marshland) flora occurred.

Collecting localities—and there are few—are frequently uncertain stratigraphically, and the beds distinguished by local names, without reference to other localities, thus needlessly complicating the issue. Confusion has also accrued by using names in two senses, e.g. the Gilboa trees occur below the Gilboan zone and not in it.

There are, however, five Upper Devonian—Lower Carboniferous genera that are good indexes. Two are probably upland, three marshland forms. Associated plants may be interesting botanically, but, taken by and large, have little stratigraphical value to date.

Callixylon is ' predominantly a Devonian genus ' (Arnold), *Pitys* as certainly a Lower Carboniferous type ; *Archæopteris* (*Palæopteris*), again, is Devonian, while

Telangium and *Rhacopteris* are characteristically Lower Carboniferous forms. Each has a wide geographical and a short geological range, each is fairly common and even fragments can generally be recognised.

As a debating point for the purposes of this discussion therefore, it is suggested that the Upper Devonian—Lower Carboniferous flora is a unit, but that it could be subdivided into an earlier, characterised by *Callixylon* and *Archæopteris*, and a later with *Pitys*, *Telangium* and *Rhacopteris*. (Admittedly *rare* examples of the last two have been found at higher levels.) Other members of this flora are rare or long-ranged.

Dr. T. S. Westoll.

The standard vertebrate faunal successions of the higher Devonian are in Scotland, Spitsbergen and East Greenland. The broad ' zones ' (based mainly on Antiarcha) are of wide application. In East Greenland, Säve-Söderbergh has recognised the following zones and correlations :

Upper Sandstone Series	up to 120 m. +	? Dinantian or Namurian.
Arthrodire Sandstone Series	up to 500 m.	? Devonian or Carb.
Remigolepis Series	up to 800 m.	Devonian.
Phyllolepis Series (+ *Bothriolepis*)	up to 700 m.	
Bothriolepis Series (without *Phyllolepis*)		

The *Phyllolepis* Series must be correlated with the highest fossiliferous Old Red Sandstone of Scotland (Rosebrae, Dura Den). In Fife the Dura Den horizon is only a little below the accepted base of the Carboniferous, and there is no sign of marked unconformity. The *Remigolepis*-fauna has not yet been found in Europe, and these beds, though containing an Old Red Sandstone type of fauna, may be contemporaneous with the lowest Carboniferous elsewhere. This is in agreement with the evidence of fish-faunas occurring in Famennian rocks. The most primitive Tetrapods (Ichthyostegalia) occur in the *Remigolepis* Series with the last *Phyllolepis* ; exact age-determination is thus a matter of considerable interest.

Mr. V. A. Eyles.

The paper deals with the Ayr and Kilmarnock districts of Ayrshire. Here there is complete conformity between the two formations. Very little palæontological evidence is available as to the age of the beds classed as Upper Old Red Sandstone, but the scanty fish-fauna recorded supports their assignment to this formation. In addition, the beds are very similar lithologically to the Upper Old Red Sandstone in other parts of Scotland, being predominantly red in colour, and containing numerous cornstone horizons. On the other hand, there is an interbanding of the lithological types characteristic of each formation at their junction, and a recurrence of Upper Old Red type of sedimentation, including cornstones, some hundreds of feet above the base of the Carboniferous.

Mr. E. H. Davison.—The solubility of rocks.

For the past four years the author has carried out experiments to determine the solubility of various rocks, and he read a paper on the subject before the Mineralogical Society in June of last year.

The method employed is to crush the rock to pass a 30-mesh sieve and lie on a 50-mesh sieve and then leach the crushed rock by aerated, distilled water. After five leachings with the same lot of water it is evaporated to dryness and weighed. This operation is repeated 25 times.

The rocks so treated included granite, gabbro, granite porphyry and oölite limestone.

In the case of each rock an appreciable amount of dissolved material was obtained, the weight being between 1·1 grams and 1·3 grams.

The graphs representing the successive leachings of each rock were not simple curves but showed high and low solubilities in succession.

It was noted that in the case of the granite the dark micas were attacked very early in the leaching and developed a halo of limonite.

Also in the case of gabbro and oölite limestone, calcium carbonate went into solution and was, to some extent, deposited between the rock grains.

* * *

Mr. F. W. Anderson.—Algal limestones in the Calciferous Sandstone Series of East Fife.

The Calciferous Sandstone Series in East Fife is composed of arenaceous, argillaceous and calcareous deposits laid down in a shallow brackish-water lagoon. Periodic marine invasions alternating with extreme shallow water and coal-swamp conditions imposed an irregular rhythmic order on the sediments. Correlation with the Calciferous Sandstone Series in other parts of Scotland depends largely on the possibility of identifying a similar sequence of rhythms. Correlation with the Lower Carboniferous beds of northern England can only be approached by a study of the periodic marine episodes in the Scottish deposits.

Many of the marine limestones in East Fife contain calcareous algæ and a detailed examination of these suggests that they must have been formed under very special conditions. In spite of great differences in external appearance these algal limestones have several features in common—they all contain abundant detrital quartz, they all show signs of pene-contemporaneous brecciation, and usually some degree of dolomitisation. These characteristics point to a static condition in a sea-floor which was silted up to its highest limit, and if this was due, as is believed, to regional and not to local tectonics, algal horizons should be of value in correlation over wide areas.

Mr. F. W. Anderson.—Ostracod zones in the Wealden and Purbeck beds.

Any attempt to establish a zonal scheme for the Purbeck and Wealden succession is more than usually bound up with the study of facies. In the Purbeck-Wealden lagoon conditions varied constantly from fresh-water to brackish with periodic marine episodes, complicated during the Lower and Middle Purbeck by rapid evaporation which resulted in the deposition of gypsum and rock-salt. Ostracods appear to be particularly sensitive to changes of salinity so that the faunal assemblage was constantly changing its character. At the same time the several gens composing the ostracod fauna were evolving and periodically throwing off new species. Out of this plexus of changing forms and variable conditions it is possible to distinguish a broadly outlined scheme which may be regarded as a zonal succession.

Within this zonal scheme, the marine bands, though containing no specially diagnostic forms, allow of further subdivision.

Five zones are proposed for the Purbeck beds to be indicated by the species *Candona bononiensis*, *Cypridea granulosa*, *C. fasciculata*, *C. punctata*, and *Langtonia setina*, and five for the Wealden to be indicated by *Ulwellia menevensis*, *Cypridea tuberculata*, *Morinina dorsispinata*, *Candona henfieldensis* and *Ulwellia clavata*.

Mr. L. Wager.—The trend of fractional crystallization of basalt magma.

ADDRESS TO SECTION E.—GEOGRAPHY

By A. STEVENS,

PRESIDENT OF THE SECTION.

The most conspicuous geographical concept whose enunciation is associated with British geographical thought is that connected with the phrase, *Natural Geographical Region.* In spite of much—rather sporadic—discussion, the concept remains obscure. Many who would like to employ the term are shy of it : they shorten it to *natural region*, and some limit the meaning of the epithet *natural* to the physical, the inorganic ; they distinguish the geographical region ; they refer to economic, to ' human use ' regions. All this hedging about terms is a sure indication of uncertainty of grasp as well as of diversity of view. And yet, if the concept, natural geographical region, were clear and well defined, and recognised as the fundamental object of geographical study, a foundation would be laid for one real school of British geographical thought in which many, if not all, could find ground for co-operation.

Search in the writings of Herbertson reveals the idea to which we are devoting this hour as a conceit rather than a concept, if we may revive a distinction fast becoming obsolete. It is true that the main force of the master's teaching is not to be found in his written word, and regrettable that his germ of thought seemed to miss a medium in which it might have developed to fruition. In his papers dealing with the matter Herbertson spent himself in analogy instead of inquiring whither the new concept might lead. If not he, then some of his disciples were caught up in the momentum of the pendulum swing away from the use of political divisions as regional units, even when realising nevertheless that the most satisfying examples quoted as natural regions showed human, and in some cases a kind of political, unity as their real index. The major natural regions which Herbertson defined were, as is well known, essentially climatic regions. I imagined that somewhere Herbertson indicated a belief that in similar natural regions the course of human development might be expected to follow similar lines, but it is first in a paper of 1927 by Roxby that such a view becomes explicit in work by one of the Oxford school.

The concept of the natural region is associated with the normal indications of inevitableness and universality. We need not search for its Lamarcks and Erasmus Darwins beyond the days of Ritter. Hettner in Germany and Vidal de la Blache in France converged in thought with Herbertson. In practice the French seem to us to work on the sounder lines : they are happy and fortunate within the limits of their *pays* so long as they have sufficient traditional knowledge to guide their selection of region. They have not, it appears to us, adequately examined the basis of their limited success. The Germans, on the other hand, have gone most thoroughly along the same path as we, but far less falteringly. With unsmiling thoroughness they have achieved a ludicrous

reductio ad absurdum and never appreciated it. To *Landschaft* they have added *Kulturlandschaft*, employing the German vernacular in two different senses in a pair of related terms. Would their risibility have withstood the step of consistent thoroughness to *Kulturland* and *Kulturerdteil*?

The term originally used by Herbertson was *natural geographical region*. In most writing the middle word is dropped. Roxby says that a natural region is characterised by a particular set of physical conditions. We quote him, not because he sins more heinously than the rest of us, but because he thinks clearly and writes better than most. But a uniform set of conditions is hard to find extended over a region of any considerable area. This is to be expected, of course: in a sufficiently small region one would find uniformity, or 'practical' uniformity, but in a large one it is necessary to search for unity within diversity. For large areas the 'dominant' physical condition becomes the criterion. Herbertson regarded climate as dominant in the characterisation of his major natural regions of the globe, and this lapse in logic evoked serious criticism on the occasion on which he first propounded his views. The criticism was as immature as the thesis. No one, so far as we know, has entered on a systematic consideration of the geographical relevance of the various physical conditions, and an examination of this relevance would seem an essential preliminary to the establishment of dominance. Such occasional—and usually disingenuous—flirting with the question as occurs would indicate what is probably true, that any attempt in this direction is, in practice, hopeless.

Assuming the existence of a natural region in the physical sense, the obvious method by which it is to be determined is to plot on a series of maps, each for a single category, all the physical characters. By superposition of the series the natural region would be defined. It is perhaps occasionally possible by this method to get a 'core' of uniformity surrounded by a margin of greater or less extent where the primary distributions overlap. We accept without difficulty the conclusion that natural regions have not, as a rule, definite boundaries, but are separated by 'areas of transition,' and we suffer without undue discomfort the inconvenience of the indefinite. We should do better to consider whether it is not to be concluded that regions so 'determined' are unnatural and the procedure uninformed.

The usual kind of regional treatment follows a similar method, in English and German texts especially, but also in the French. The various categories of physical facts are described, and frequently they are analysed as if they were, from the point of view of geography, facts-in-themselves, and not relevant merely in a special connection. The orderly succession proceeds from geological structure through climate to technology, with varying emphasis, but little evidence of any principle of selection. There may follow or be interjected some description of flora and fauna. Then there is an abrupt change to 'human' matter, which may be pure demography or pure ethnography or a mixture. But the relation of this epilogue to what precedes is obscure. The reader has presented to him no picture of an organised whole, and has no sense of a completed job. He has a detailed description of the same graphic value as a full census of the composition of a forest. The place for such matter is a pigeon-hole, its function the amassing of dust until such time as it is disturbed by one of the unduly curious. Put the due proportions of pinions and springs and brass plates in a box and call it a clock. You will perform more reasonably

in this respect at least, that you have paid due attention to selection of material.

The ultimate fallacy underlying this kind of thought or procedure is that it begins by assuming a duality, the physical and the non-physical, the human and the non-human, the natural and the artificial. It brings geography to the stage reached by the Schoolmen when they disputed between form and matter, matter and spirit, and questioned the possibility of knowledge. We are not concerned about absolute knowledge or complete knowledge, but only about a particular kind of knowledge and only about the attainable extent of that. We are concerned with physical and biological nature only in so far as it may be regarded as human environment and only with man in so far as he has demonstrable relationships with the environment.

Many will agree well enough with this last statement, but some of them, if not all, will insist that the method of geographical study is a synthesis or an integration. In one instance the meaning attached to these words is somewhat clear. The Germans regard the *Landschaft* as a member of the *Land* and the *Land* as a component of the *Erdteil.* Among English writers Unstead is identified with something similar. He distinguishes different 'orders' of natural regions, as Herbertson did theoretically. But Unstead seems to regard natural regions of a certain order as more or less infinitely divisible, and he builds up larger regions from units to which he applies the term *Stow.* A Stow may be the valley of a brook. It is easy to see that he may achieve a good deal of physical uniformity by taking his area so small, but it is difficult to see how he can achieve anything in the way of positive unity. To add physical units is, in any case, not to perform either an integration or a synthesis. The absence of cohesion in so many 'synthetic' geographical accounts, the failure to present anything resembling a finished composition, is sufficient comment on the success of geographical 'synthesis' in present practice.

Synthesis is not addition : it is a complex process for which there are no general rules. The chemist performs it successfully, but in special and individual cases. The mathematician is our best integrater. He may begin with a function of x and is as likely to end with a new branch of mathematics as with a reasonably simple new function of his variable. Neither of these magicians can operate with dissimilar things. You cannot integrate man and his environment. Those who believe so have been carried away with a word and imagined it a thought.

I suppose something analogous to synthesis might be said to go on between man and his environment. If this analogy do not lead us astray once more, we might say that man is the synthetic influence. History is a spectator of the process, more or less blinding itself to everything but the time element. The geographer does not synthesise, because he cannot, but he also is a spectator of the process primarily interested in its development in space. Man must be looked at objectively by the geographer and even his significant antics must be taken to be as natural as the physical environment. The natural geographical region is a result of what, for want of a better word, we may agree to call synthesis proceeding in nature, under our eyes, but not by our voluntary action. There are two aspects of this synthetic product : the environmental aspect, essential to which is man himself, and the human aspect, which is much the same as to say the functional aspect, using the language of ecology.

Dissociation of these has led geographers to attempts for which they are not qualified and certain unqualified students to call themselves geographers. 'Geography,' a biological colleague used to say with reason—'what is geography? We all teach geography.'

For these two aspects of the same thing there are convenient names, but it is essential to remember that coherent geography must regard them as indicating mere aspects of the same thing. The one is *region*, and it focuses attention on the environment as space. The other is *community*, and it indicates that special attention is to be paid to the functioning, or dynamic, aspect of the case. The natural geographical region must be defined by reference to both. Otherwise it is necessary to drop the *geographical*. The physical region of 'uniform' or 'dominating' physical characteristic may interest the topographer (in the survey sense), the climatologist, the pedologist. It is an irrelevance in geography.

With natural perversity various writers have seemed to approach this way of thinking and shied away from it. For your iconoclast is but the prophet of a different idol and nihilism is but the technique of the quack vendor of another political nostrum. The too enthusiastic, and the disingenuous, thinker, each has a fatal attraction to the false analogy and the undefined term. We must inquire what may legitimately be meant in the language of geography by the totality, the unity, the functioning and the evolution of the natural region. As to the first, there are some innocent souls who take it absolutely. Encyclopædism died with Diderot: we may leave them to their quest of All Knowledge. We may smile gently at their efforts to train Jacks of All Trades, wryly at the contribution they make to geographical repute. Unity within diversity, active functioning, progressive evolution are all to be associated with an organised whole, and it is this organism we have to seek, to study, to define. Let us embark on the perilous sea of Analogy: with due consideration of the uninsurable risk of this kind of navigation.

The naturalist is familiar with the idea of an organism growing in a suitable medium and so permeating it as to produce an indivisible whole of organism and environment. The image is perhaps more striking where the environment is itself living: *sacculina* in the crab, a cancer in the human body; all the phenomena of parasitism and symbiosis. The image is the same if we think of the mycelium from a mushroom colony permeating the manure heap prepared for it. Hear the parable of the gardener transferring to a suitably small pot of compost a seedling he is 'bringing on.' In course of a remarkably short time the whole pot of soil is invaded by roots, but the plant-pot-of-soil remains a growing and perfecting synthesis until there appears clear evidence of distress in the seedling and roots begin to emerge from the soil. The system has then reached a stage of decadence and must perish and be succeeded by some other. But had the pot been stood in the garden, and not separated from all continuity with soil, while the roots were still in a state of rampant growth, and long before the pot-bound condition was reached, they would have pushed out through the drainage hole, and at the cost of some energy and inconvenience, the system would have been extended in space and in time. On the other hand, had a tiny plant been set in a nine-inch pot, long before it had grown into competence to deal with its accessible medium the greater part of the soil in the pot would have been 'soured' and again extinction

would occur, premature extinction. Let it be noted that while the gardener's most active interest is in the pots that contain his plants, he is not indifferent to other pots or other soil which in the future he may come to use. He stops short of becoming a pedologist before he dare plant a lettuce, of considering the processes of weathering before he throws out his exhausted or soured soil for nature to deal with.

The natural geographical region must be an organised region. The organising agent is the human community : community and region are but aspects of the same organism. It may be suggested that the morphology of this natural geographical region is the interest of geography—its morphology as a whole, not its histology, and not directly its physiology. Quite outside the subject lie those studies such as geology, geomorphology and climatology, which deal purely with the environment and have proper dynamic problems of evolution or change. Without it lie also those studies which are concerned with man, the individual or the community. The limits dividing these disciplines from the geographic must be clear-cut. History alone seems impossible absolutely separate from geography. The besetting sin of the geographer who trespasses is the adoption of the alien point of view.

The boundaries of the natural region (in our sense) are definite enough ; which does not mean that they are necessarily simple or easy to trace. Where they are common to another natural region they are clearest. These boundaries indicate a state of equilibrium which may be stable but cannot be static. Change may occur in their position or in their condition. The most active normal change occurs when they are advancing unto unorganised country or relatively unorganised country. Such advances occur during colonisation, even if that proceeds overseas. Their tendency is centrifugal, their actual development in space is limited by conditions. Organisation by Rome was more or less regularly centrifugal, the advance of Germanism was eastwards. The boundaries of a natural region may be indifferent to natural (physical) boundaries. For an organism must have continuity in its medium, but continuity does not preclude variety. So the boundary of a natural region may cross a mountain range, partition a river valley, divide a coalfield. And it may be a better boundary for so doing. The time factor (*relative* time) is important here, for the question of stability, equilibrium, is a question of adjustment. It is no hardship to the economic structures concerned that France, Belgium, Holland and Germany share one coalfield. Their political frontiers antedate their industrial development. For the Romans the Rhine divided, for the Germans it unites, for the French it still separates. The flanks of a mountain range separate and are easily held ; the passes connect.

For Herbertson with his analogies man represented the nerves of a natural region. Not so : man is the living principle. The nature of that principle is not the subject we are called to study. The nervous system, if we must have analogy, is the means of communication in the widest sense ; and the analogy is unduly narrow, for means of communication have nutrient as well as co-ordinating functions. In this place, it is true, we are less concerned with the former, for the purpose is to define the natural geographical region.

The unity of the natural geographical region is achieved, maintained and developed by organisation, by cohesion, and this cohesion is attained and extended by intercourse, at first within and later beyond the region, provided

the organic development is an indigenous growth. Since the fourteenth century the means of communication of the type associated with Western Europe has been undergoing continuous but uneven development. This development was stimulated by overseas discovery, but its progress gained speed of a new order in the nineteenth century with the concurrent development of railways and large-scale manufacture, and the acceleration has progressively increased until our day. In consequence the range and intensity of organising ability and power have increased. The most satisfactory natural regions to contemplate, and to appreciate from geographical writing, had been fully organised and had their identity recognised before the modern era began. One has but to think of the French *pays*, and the deterioration of the work of such a master as Vidal de la Blache beyond the Paris Basin. No doubt the conservatism of the French countryside and the degree to which it was able for so long to preserve its archaic cohesions has made it a specially favourable field for regional studies. But traces of such a division of the country are not wanting in Scotland. Even in the Midland Valley names like Menteith and Lennox have not completely lost regional content, while names of regional significance are common enough north of the Highland Line. Elsewhere access to extraneous sources of necessities and the means of establishing wider loyalties have obliterated local character and submerged local unity. What are the *pays* of the Rhone Valley ? The speed of modern change has confused a great deal of thought.

There are minimum and maximum sizes for natural regions. The minimum is determined by the least extensive area, in extent and variety of natural endowment, capable of being organised and maintained, by its resources, physical, biological and human, for cohesion, sustenance and defence. The maximum is determined by the efficiency and range of means of communication. Both maximum and minimum vary in time.

Two types of organisation must be distinguished, and we shall call them conscious and self-conscious respectively. The former is primitive and appears less artificial. The latter is very modern. It is a development made possible by progress in general, especially in the knowledge of the possibilities of 'planning,' and of the 'management' of environmental conditions ; and in the development of means of communication in particular. The objective view of man excludes the possibility of regarding his actions as artificial. Some of them we may think ephemeral or capricious, but they have their source in the nature of man.

Natural regions must change in extent and otherwise with time, but the changes need not be continuous. At times of specially rapid change in human life the natural division into regions may almost suffer a revolution. But a true revolution, a sudden and catastrophic change, has occurred only in extra-European countries. In North America there must have been natural regions —or, if it is preferable, an analogue of a system of *pays*—of Indian times. The traces of these have been swept away, except what may be gleaned from such knowledge of tribal distribution as has persisted. We must distinguish natural regions of continuous and of discontinuous development.

The train of thought here presented arose out of consideration of two cases, one of continuous and the other of discontinuous development, Russia and the United States. As we go eastwards in Europe the scale of the current 'natural

regions ' increases, their characterisation becomes looser, the criteria on which their discrimination is based alter. This is explained, of course, by the disappearance eastward of ' marked ' features, the apparent poverty in variety, and so forth. It is also due to meagreness of information, whether absolute or relative to the individual writer. The division into soil or vegetation belts or into topographic basins and intervening plateaus, or the adoption of the new Soviet administrative divisions may satisfy the botanist, the geomorphologist or the student of administration : they ought not to satisfy the geographer. In Russia it is possible to distinguish very clearly four organisms developing under auspices which may be called indigenous and a fifth stimulated by agencies initially external. To none of these can completely determined frontiers be assigned for a reason which will appear later, but it is evident that these boundaries will pay little heed to the ' natural ' boundaries we are accustomed to recognise. The regions are respectively that which was Novgorod and now is Leningrad ; Muscovy or the Moscow region, which the Soviets subdivide administratively ; Kiev—the traditional division into White, Great and Little Russia, more or less. The fourth is the Central Urals, or the Chusovaya-Ufa Valley region, and, in a sense, is a successor to an older Permia, with which it does not coincide. The fifth may be called the Azov-Black Sea commercial and industrial region, and owes its differentiation to trade in wheat and to Franco-Belgian interest in its industrial materials. It is not really hard to find other natural regions to fill up the country, but their characterisation is less definite and their limits very uncertain.

In the case of North America the divisions customary in regional description are based on criteria mainly of two different orders. They are the topographic regions and the ' human-use ' regions. Such shifting of ground is not scientifically sound nor is it intellectually satisfying. On the criteria now proposed it seems possible to distinguish in the whole of the United States but two divisions east of the Cordillera : New England, and a region corresponding to the State of Ohio with Indiana and part of Illinois—more or less. Here, as in Russia, is much unorganised territory : in both the regions are more extensive than in Western Europe.

The difference in scale would appear to be due to difference in topographic fragmentation—before due consideration has been given to the matter, as long as we consider the physical more fundamental and permanent. But it is neither. What is fundamental is relativity to man. Space, height, slope, areas at the time unproductive, all these represent difficulties in the problem of instituting and operating means of transport. At the present moment all of them within terrestrial limits have their price in time, labour, ingenuity and risk. If the price is commercially—and even strategically—still too high, the practical possibilities are still of commercial magnitude. It is only a hundred years since the scale of land transport began to approach that of water transport. Crossing the Alps by forces of great military significance was almost as great a marvel in the days of Napoleon as in those of Hannibal. It was less perilous than the invasion of Muscovy. What strength in men and material could be launched across these obstacles of space and altitude to-day ? What ' fifth column ' of 1940 can be certainly held at bay by the most powerful or secluded or distant people ?

The Natural Geographical Region is an active organism. The size of a

region growing freely is determined by the range of the means of cohesion. At a given time that range depends on the state of technical development of the community occupying the region in relation to the problems presented by the nature of the medium. If technical development is relatively stagnant, but territorial development is undisturbed, the ' organism ' will expand up to boundaries which for topographic reasons, but also, it may be, on account of mere distance, are insuperable at the time. The state of equilibrium so reached in empty, barren or distant areas will be fluctuating. Improvement in the means of communication will produce an expansion of the organism, provided it is free to expand. In a ' new ' country like the United States, that is, where the history of development is discontinuous, to the expansion of regional units are set the very wide limits compatible with modern means of communication.

Efficiency of communication may become uneven. Long distance communication and bulk movement of commodities have undergone hypertrophy, while the more intimate contacts which produce ' neighbourliness ' are weak. Very large areas may be fed, policed and defended. National organisation is in a stable condition. In such conditions natural regions of the order of *pays* are never likely to develop, or, at least, to have more than a very ephemeral existence, until population densities are very different from their present condition. If regional unities of the nature of *pays* develop they will be on a vaster scale.

Some at least of the commonly recognised regional divisions both of Russia and the United States are represented, mistakenly of course, as regions of monoculture with a characteristic crop produced under suitable climatic conditions. In fact, the corn belt is as much a region of mixed farming as the dairying belt and there is a great deal of pasture, largely unimproved, in both. The pressure of population on the land is low, and the region-community organism is far from the condition to which the ecologists apply the term *climax association*. A state of equilibrium has not been attained. Two propositions follow from these considerations : the relation between the community is so loose that its activities do not fully reflect the conditions of the environment ; the more intimate and less organisable contacts within the community are so indefinite that what we may call regional consciousness is rudimentary. At the same time what we have referred to as self-consciousness is of an advanced type. The ' human use ' region, as usually distinguished, is an area of undeveloped economy. The natural geographical region emerges from chaos only when it has evolved to the stage at which it can be clearly recognised as a synthetic whole with what the French would call ' personality.' When this stage of climax association has been attained we are able to assess the relative significance of environmental (physical and other) factors ; for this cannot be done satisfactorily except by using the nature and activity of the community as an index in the same way as the natural vegetation of a region has been employed as a climatic index. The climax condition when it has been attained is not necessarily permanent. It may change with greater or less rapidity in time, and the obvious reasons for change are human progress, chiefly technological, or the reverse, and exhaustion of resources, notably mineral resources, absolutely or due to alteration of values.

I do not know whether Russia ever reached a ' climax ' condition. If we think of the shortness of modern Russian history as such and of the slowness of progress towards the condition aimed at now, we might easily think not.

Pressure of population on the land was certainly locally heavy, but perhaps in general light. Even here there is a doubt, because there is a factor in intensity of pressure on the land other than mere size of population : what is demanded of the land, economic level. Isaiah Bowman held the view that grain export from Russia went on in spite of grain deficiency, and even the Soviets found it necessary to work on the principle enunciated later in a different application as, Guns before Butter. The spasmodic entry on the strait and narrow road to a paradise made in the image of Chicago has so altered Russian circumstances that the conclusions we have reached in regard to the United States may apply in the case of modern Russia also ; though this does not imply that the two are at the same stage in the progress to synthesis.

In the more westerly parts of Europe the centrifugal processes were propagated from a number of centres during the course of development to present conditions. Through a great deal of it something like climax conditions were reached before the railway era, and to these conditions belong the French *pays* and the German *Gau.* Such entities occur east of the Rhine only within the sub-Hercynian belt of dense population, and not throughout the belt. In the extreme west they expanded territorially up to natural limits which, being narrow, kept them small. Had these close natural limits been wider the *pays* would have been limited by the advancing peripheries of other organisms and conflicts would arise which would be stilled only by coalescence into larger organisations by one of the methods known to history. Indeed the *pays* as we know it is no doubt a product of coalescence : as the smallest organism of the type, available for study, it may, merely for convenience, be regarded as indicating the practicable minimum. In areas more remote from the influences active in western Europe, and to the east in particular, slower progress in indigenous technology, greater obstacles to cultural importation, and correspondingly less rapid growth in population, absolutely and in relation to the extent of available territory, deferred to a comparatively recent date the attainment of the climax condition. The broader fragmentation of the country was a concomitant, but not at all necessarily the dominant, determinant of the territorially larger organism.

Long before the railway era France and this country had achieved the more self-conscious organisation of the nation-state by coalescences of various kinds. The process was less satisfactory in Spain. All three were able to relieve the unease to which increasing efficiency of means of communication made them liable by overseas adventure keeping step with that growing efficiency. The relief was illusory in the case of Spain. Germany had respite of a similar kind because she had her colonial area to the eastwards, and there she still has colonial spaciousness even within her present restricted bounds. In that direction also lie some of her deracinated offshoots, as others share the United States with ours and the French are to be found especially in Canada.

It is suggested that the European nation-state is a community occupying a natural geographical region as its immediate environment, because it is a natural growth limited by its geographical circumstances. Not only so, it is an organic phenomenon so characteristically European in its genesis, to be found nowhere else in a state of mature development; and therefore any European geography which failed to take account of it, indeed of which it was not the central object, ought to be unthinkable. The swing away towards the

novelty of the physical reason was a vain pursuit of novelty. If the real natural region for geographical study is as we have held, and if the nation-state-country organism of Europe is the achieved synthesis of European geography, then the region which is characterised by a set of physical attributes is, geographically, a misconception. For not only have many European states partitioned one of the main ' natural divisions ' of the continent among them by stable frontiers, but it is unthinkable that any one community could develop that area as a whole and remain restricted to it. We refer to the North European Plain ; but there have been attempts enough to unify the ' Mediterranean ' region, and there is sufficient division now and throughout historic time both there and in the Alpine region, where physical conditions favour severance rather than unity, to justify the same statement with regard to them. Physical conditions are neither more permanent nor more fundamental in geography than human. If in themselves they change less quickly than the characters of the living partner in the symbiosis, their significance and value changes rapidly, even suddenly, and sometimes disappears. And we do not really believe in the permanence or significance we predicate. For we approve and wish to maintain the further political subdivision which has taken place so recently in the North European Plain, we see reason in the demand for access to the sea or to a navigable river, but we boggle about allowing more than one nation access to a coalfield.

These views bring geography nearer to reality, nearer to a real task, closer to the ' man in the street.' They bring it back to earth and make it—and the services of its devotees—marketable. There are various ways of indicating repute, and that is as sound as any. In these trying days when every effort is required to understand and deal with perplexing problems it does not seem that, at least in this country, geography has made, or shown much sign of ability to make, a due contribution to the common effort. It will not so long as students of geography can gravely read a statement with regard to the subject such as this : ' Geomorphology together with climatology in its widest sense . . . appear in fact to constitute at least half of the legitimate field of the subject.' What might be the fore (or after) end of this heraldic monster of a subject ? If the geographer contents himself with doing with 25 per cent. of normal efficiency what is legitimately done by geomorphologists and climatologists, and *pro rata* with regard to any other disciplines in which he may consider himself free to dabble, can he claim to have a function of his own, and can he be regarded seriously ? In clamouring that his subject is the Cinderella of the sciences let him remember that no Cinderella finds her prince among the cinders.

The study of the natural geographical region in being and in development offers the possibility of making in fact that contribution to human well-being which is claimed by history and can never be made by history alone. It offers suggestion, perspective and balance to those who have the conduct of affairs. In dealing with new countries its task must be to follow and understand evolution in progress at a given time. In older lands it is concerned with problems similar to those involved in keeping an archaic piece of machinery working as smoothly as may be. But it is also concerned with the necessity for renewals and for modernisation without the possibility of wholesale scrapping. The nation-state is certainly a synthesis, whether one is willing to call

it a natural region or not. It is the major unit of Europe, of whose nature and working we must give geographical account. We must distinguish within it its members and understand their several natures and functions. These are the proper minor natural regions. *Pays* and *hoc genus omne* are archaisms, primarily the concern of the geographer with archæological leanings, the historical geographer, without whose services any balanced regional morphology would be impossible. And regional morphology of the actual functioning geographical individuals of our time and of their members is the contribution towards human well-being required of geography.

We see the countries of Europe as natural regions, natural because they exist as phenomena demanding study, demanding it with a special urgency in these days. Their territorial development seemed to have culminated before the war, and before the present unrest it underwent readjustment which seemed to offer some prospect of stability. We must look for objective explanations of failure. These states grew into contact with each other and organisation permeated the whole of, or the more ' European ' part of, the continent. Not natural boundaries, but convergence of organisms set limits to expansion, especially for the later developed units, at a time when means of organisation were developing rapidly. The proper scale of organisation is no longer represented by the European nation-states but rather by the United States. Disturbance of equilibrium shows itself by unrest in the newer countries which have not been disciplined by long confinement within narrow bounds and had their views of hegemony chastened by such a loss of territory and influence as the French suffered in the complete rape of an earlier empire, the British in the loss of their earlier colonies in America and by the development of increasing independence in the Dominions. For the countries east of France the region of colonial expansion has been continuous with the homeland ; the peoples of slower development whom they have replaced have been Europeans and have survived the disturbance of colonisation. These countries do not appreciate the barbarity of applying in 1939 the moral principles applied by others in ruder times two centuries ago.

In Germany we can distinguish extensive areas over which the mean density of population is comparable to that of this country. But to the east, especially, the Reich has extensive areas of relatively recent occupation which we have called its natural colonial region, that which it has in fact exploited, whether of choice or of historical necessity. There the mean density of population is scarce half as great. On the other hand, the former kingdom of Saxony has proved capable of maintaining a mean density twice that of Great Britain. The urgency of any problem of *Lebensraum* is fanciful. And straitness of living space is commonly relieved by more or less free movement of commodities from abroad, compensated by similarly free exportation. Voluntarily or involuntarily Germany has to a large extent renounced this relief. The *malaise* seems by no means untreatable by other means. Germany is sensitive to, if not conscious of, the disproportion between the power to organise and rule and the space to be organised and kept in order. She believes in a *Mitteleuropa*, whatever theorist denies its legitimacy on ' natural ' grounds, and with reason. She could not contemplate the possibility of herself having lost the United States as we did. Were her colonies not ' stolen ' at Versailles, while her acquisitions from Denmark and Poland were legitimate conquests to

be made as soon as she had accumulated allies sufficient to deal with the hordes of the Danes and the cohesion of the Poles? The tenacity with which a view is held is often in direct proportion to its absurdity.

These countries of Europe are on a scale, relatively to each other, to maintain their identity, either individually or in groups, both against natural tendencies and against human enemies; for the doctrine of the Balance of Power has re-emerged. Their military strength, their means of centralisation and direction, their facilities for developing common 'opinion' have all increased with astounding rapidity. They have learned the workings of what we have referred to as the more intimate means of cohesion, and developed the knowledge as the applied science of propaganda for offensive and defensive purposes. In a world of crises the word is all of threats and security. There is a part of Germany called the Bay of Leipzig, once a region of corn and beer, now the land of lignite. Here coal tar is abundant and electricity is cheap. Self-sufficiency is a means of security, and self-sufficiency calls for the substitute, the *Ersatz*. We may indicate the function of this region in modern Germany by dubbing it Ersatia. The Ruhr is threatened by the French, Upper Silesia by Poland, and both are inconveniently marginal. Does Germany see in Ersatia the heart whose beating must be her life in any future struggle? Czechoslovakia threatens it: her liquidation is imperative politically. There is money in *Ersatz*, especially in war: the industrialists are interested: the step is practical politics.

This is the kind of suggestion which geography can offer for consideration from the study of living geographical entities and their members. The usefulness of the suggestions must be tested by those whose function is to apply them. They require to seek counsel at the oracles of geographv and history. Does the cult of the deities receive due and pious attention?

SECTION E.—GEOGRAPHY

COMMUNICATIONS

Mr. K. H. Huggins.—Town development in Scotland.

In Scotland in the last 150 years there has been a three-fold increase of population and a still more rapid increase in the number of town dwellers. The present twenty-four largest towns contain over eight times as many people as in 1801, and over half the population of Scotland.

The individual towns have specialised to varying degrees on different functions and consequently each has different prospects for the future and different problems to solve.

Their future is all the more important because the number of people in the rest of Scotland has been declining for the last quarter of a century, and consequently even the maintenance of the present numbers depends on the future prosperity of these towns.

From the examples of selected towns the changing values of certain geographical factors are considered; also the degree to which the present distribution of urban population in Scotland is adjusted to contemporary conditions.

Mr. A. J. Hunt.—Some aspects of the internal geography of Edinburgh.

Geographers will be familiar with the methods of Urban Survey worked out by Dr. P. W. Bryan in his study of the city of Leicester. During the past year a survey of the central portions of Edinburgh and Leith has been carried out on similar lines, to record the functional utilisation of every distinct building unit.

The following ten major groups have been recognised :

1. Manufacturing.
2. Transport.
3. Wholesale trades.
4. Retail trades.
5. Skilled and service trades.
6. Administration and organisation.
7. Professional.
8. Public utilities.
9. Recreation and community institutions.
10. Residence.

Results are portrayed in 25-in. coloured maps, of which four are displayed. Some of the more interesting conclusions which have been drawn are offered for consideration.

* * *

Brig. A. B. Clough.—The new programme of the Ordnance Survey.

The future activities of the Ordnance Survey will be based largely on the recommendations of the recent Departmental Committee, whose final report was published in November 1938. The events leading up to the setting up of the Committee and their terms of reference will be discussed.

Many alterations in the British Cartographic System were recommended. The principal alteration will entail the re-arrangement of the 1/2,500 plans on a national instead of a county basis. A short summary of the original ‘ county ’ policy is given, with its resulting disadvantages under modern conditions. The new plans will have a metric grid superimposed and will be square in shape. Six-inch maps will similarly conform, and a new gridded 1/25,000 series will be introduced. In the process of change-over the 1/2,500 plans will be overhauled to eliminate existing errors or defects. Small-scale maps will retain their existing scales, but will have a metric grid. The Committee recommended that the present system of numbering parcels on the 1/2,500 plans should be discontinued when the grid is introduced, but as a concession such parcels will probably be given a number corresponding to their grid position.

The use of air photographs in connection with revision and re-survey is discussed, and also the establishment of a new ground control involving the re-triangulation of Great Britain, which has now been in progress for three years and still continues.

After the overhaul it is proposed to adopt a system of continuous as opposed to cyclic revision. This will entail changes in technique as regards the drawing and reproduction of the large-scale plans.

Up-to-date and accurate maps on all scales are essential to modern social life and development, and it is hoped that any future wave of national economy will not again retard the activities of national survey.

* * *

Lieut.-Col. R. Ll. Brown and Capt. E. H. Thompson.—Air photography and the Ordnance Survey.

The first air survey problem confronting the Ordnance Survey was the revision of the 1/2,500 plans. The photography is more exacting than for smaller scales.

Only simple methods of plotting are used so as to allow of mass production, and these methods are described. The cost of ground revision varies with the locality and the development from 2*d.* to 6*s.* per acre and results show at what point the air photograph becomes economical. While air photographic methods are more sure in a general plan position and orientation, ground methods are better in the interpretation of minutiæ of detail.

The second problem is the overhaul of the 1/2,500 plans on national sheet lines, and a further use of air photographs may be for tertiary triangulation. A new stereo comparator designed for this purpose and its various uses are described. The results of work with this machine are set forth.

Mr. D. L. Linton.—Some aspects of the evolution of the rivers Earn and Tay.

It is well known that the relief of the Central Lowlands of Scotland is so closely adjusted to geological structure that its main features may be adequately described solely in terms of differences of rock hardness. In these circumstances it is useless to seek evidences of the original drainage pattern in the lowland areas opened up on the softer outcrops. Such evidences, chiefly in the form of incised river courses, abandoned high-level valleys and wind-gaps, are likely to be found only in the elevated, resistant tracts. In the Campsie-Ochil-Sidlaw uplands the most conspicuous features of the kind are the water-gaps at Stirling and Perth, and such wind-gaps as those of Glen Eagles and the Glack of Newtyle, and several writers have deduced from them an original south-eastward flowing consequent drainage. Such an hypothesis is however not consistent with the evidence of east-west high-level valleys in the Ochils, or with the Forfar, Brechin, etc., gaps in the Sidlaws. The alternative of an initially eastward-flowing consequent drainage is therefore advanced and some of its implications discussed.

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Prof. T. M. Knox.—The palm oil industry.

The economic prosperity of Southern Nigeria depends on the native exploitation of the indigenous oil palm forests, and this industry is now jeopardised by the creation in Sumatra of a European-managed industry based on plantations and oil mills. Native methods waste half the oil content of the palm fruit and produce an oil of poor and irregular quality. European methods avoid waste and produce oil of a constant and high quality, but the introduction of such methods into Nigeria has hitherto been impracticable owing to the Government's policy. If the Nigerian industry is to survive, some revision of this policy is essential because (i) the price offered to the native for his oil is already depressed as a result of the eastern competition and some buyers of oil refuse to accept the Nigerian oil because of its quality ; (ii) the success of the native cocoa farmer cannot be used as an argument in favour of the continued success of the native palm oil product ; (iii) it has proved impracticable to persuade natives to sell palm fruit to European mills ; (iv) without an income from the oil palm industry the native might survive but could not be prosperous.

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Dr. N. Friberg.—The development of highways in Sweden.

The Swedish road system has to a very large extent been conditioned by the geographical features of the country. Certain kinds of ground, e.g. those consisting of glacial river deposits and moraine gravel, have attracted the roads, while marsh soil or clay and the like were avoided by the traffic, especially in the early days. From the topographical point of view, the roads have as a rule gradually changed from hill roads to valley roads. In deeply sedimented river valleys, however, the

roads have largely been moved from the river banks up to higher levels. Old shore formations have often attracted both settlements and traffic. In the coast districts the land uplift has caused the roads to be moved fairly extensively.

The oldest roads branched off from a framework of waterways. Most of the long-distance traffic of the country formerly went by special winter sleigh tracks. In many places the summer roads have only recently become of any importance.

Old cross country roads can be recognised by their high phosphate contents, which is often almost proportionate to the old-time traffic. An examination of abandoned road sections has permitted a reconstruction of the nature of the ancient Swedish road system.

Communications have had great influence on settling the frontiers, and on the establishment of cultural and economic relations. A study of the network of roads will often give valuable clues to the spread of civilisation. Motoring has played an important part in economic progress of recent years, but has not yet produced any extensive changes in the conditions of settlement.

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Mr. W. Fogg.—Some aspects of the human geography of the Spanish zone of Morocco.

Brief summary of relevant details of physical environment.

Summary of origin, development, and relevant characteristics of each of the towns, and of relevant characteristics of typical settlements other than towns.

Summary of relevant characteristics and functions of the tribal markets, and of relative importance of latter in economic and social life.

Deduction from foregoing that relative lack of urban centres seems to be due mainly to cultural conditions ; correctness of which seems to be supported further by developments since establishment of European control.

* * *

Mr. G. Bowen.—Sheep and cattle ranching in Western North America : An example of extensive land use.

The Great Basin belongs largely to the category of lands in which pastoralism represents the best use of the natural resources. Even irrigation farming is supplementary to, and economically dependent upon, the exploitation of large areas of steppe and semi-desert as grazing land. The adaptation of livestock raising to the environmental conditions of the Great Basin has been achieved after sixty years of experimenting by the methods of trial and error. To-day the semblance of stability can at last be observed.

A ranch, covering approximately 1,000 square miles on the north-west margin of the region, has been chosen to exemplify, in its land holdings and operations, some of the problems which are encountered in the running of livestock on an extensive basis over poor steppe country. The migratory character of the enterprise, more evident in the case of sheep, is determined by the seasonal availability of pasturage. The land holdings and use are organised to give the operator control of suitable grazing lands for the four seasons of the year. But the greatest foresight and industry cannot wholly eliminate the large element of risk which arises from the extreme variability of the climate.

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Mr. T. W. Freeman.—Current movements of population in Éire.

The redistribution of population in Éire is reflected in the returns of the 1936 Census, which showed a slight decrease in the total population and a rise in the urban areas approximately equal to the decline in the rural areas. The larger towns show the greater increases, and Dublin the greatest of all. The tide of external

migration is not checked, though changed in its main direction from the other Dominions and the United States to Great Britain and Northern Ireland. The movement from Éire is primarily of the labouring classes, but also includes many young professional people. It has resulted in the continued depopulation of many of the poorer parts of the country. In spite of increased prosperity attendant upon the economic agreement between Great Britain and Éire, agricultural settlement schemes and industrial developments, internal and external migration still remains as a feature of Irish life.

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Miss D. Sylvester.—The geography of Domesday Cheshire.

The distribution of population and wealth in Domesday Cheshire was broadly complementary to that of forest and upland. The fertile lowlands of the Wirral and of the Dee and Weaver valleys were the richest areas. Between Dee and Weaver lay forest, and in the east the desolate Pennine Edge. Central and Eastern Cheshire had been ' wasted ' extensively. The Weaver valley had largely recovered, but the greater part of the more easterly lowlands was still waste in 1086. Cheshire was not wealthy, a fact clearly connected with a relatively northerly position and the recent ' wasting.' The principal features of its geography may be summarised as : the contrast between the ' wasted ' East and relatively prosperous West and Centre, the progress (but temporary recession in parts) of settlement and deforestation, salt production in the three ' Wiches,' and the importance of the Dee and the port and city of Chester.

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Mr. S. G. E. Lythe.—Population changes in the Lower Tay Valley since 1755.

The use of Webster's figures for 1755 enables us to describe the distribution of population at a time when agriculture remained ' unimproved ' and when the modern concentration of industry had scarcely begun. An examination of the predominantly rural parishes in this area shows that the depopulating effects of agricultural changes in the century after 1755 were partially offset by an expansion of other forms of employment, e.g. fishing and hand-loom weaving. There was, however, a measure of short-distance townward migration even before 1800, and there is some evidence of a centripetal movement in rural parishes towards the larger villages.

Down to about 1800 the two main towns, Dundee and Perth, grew at much the same rate. After that Perth suffered from its less favourable location, and, despite improvements to the navigation of the channels westward from Newburgh, it lagged behind its ancient rival. Dundee was now attracting migrants from three main sources : (*a*) local, (*b*) the Highlands, (*c*) Ireland, and with better transport facilities its wealthier residents moved out to dormitory suburbs on both banks of the Firth of Tay east of Dundee. After the middle of the nineteenth century Dundee's pull gradually decreased, and there was considerable overseas emigration from the region.

The concentration of manufacturing industries threatened to depress the smaller burghs. Those easily reached from Dundee attracted a suburban population ; those with special advantages of location or resources developed new forms of employment ; the rest, and most of the rural parishes, stagnated or declined.

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Mr. A. C. O'Dell.—The geographical background of Scottish sea-borne trade since the Union.

There have recently been made available in the Register House (Historical Room), Edinburgh, the MS. Customs House Accounts for Scotland, which give full details of imports and exports of dutiable goods for the period 1742–1831. These have been analysed at ten yearly periods, supplemented by a yearly analysis of certain commodities, as tobacco. The statistics or commodities so obtained have been

extended where possible by the Annual Statements of Trade and Navigation for the more modern period and amplified for the earlier from local and trade histories.

It has been found that the ports of Scotland reveal in their trade items, even at the present time with rapid land transit facilities, a marked regional background. This bias of the goods handled is not simply controlled by the mineral and agricultural resources of the immediate hinterland of the port but also by long established industries (of which the textiles of Dundee form a most striking example), leading to a specialised set of imports and exports. In the pre-railway era the many small ports of Scotland, now often represented by grassy quays as at Wigtown, had a trade confined to, and therefore closely reflecting, the activities of the immediate countryside. The rapid expansion of Scottish trade after the Union is revealed both as regards new countries of trade and also by the increased import of raw materials from the old established suppliers as Holland and the Baltic States. The coastwise movement of coal in the eighteenth century is compared with that for 1937 shown in a map based on the London Coal Bills of Lading.

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Dr. Catherine Snodgrass.—Some comparisons of population density and agricultural type in Britain and the Continent.

The agricultural populations of certain regions in Scotland and England have been estimated from the agricultural returns. These estimates, together with information regarding agricultural populations in various European countries available in the form of published maps or statistics, have been used to make comparisons of population density in some of the main agricultural regions in western and central Europe. The paper is intended to provide a preliminary survey of this important question. But while its main aim is to set forth regional contrasts it will also include some attempt to deduce the major factors affecting density of agricultural population in Europe.

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Dr. J. F. Scott.—The physical and human geography of Morvern, Argyll.

The area under consideration is the peninsula lying S. and S.W. of Glen Tarbert, Argyll. The topography is closely dependent on the various rock-types, and faulting also plays an important part. The Moine gneisses and schists give rise to rugged hill masses. The Morvern (or Strontian) granite gives similar features but is generally more easily weathered and shows the effects of glaciation more markedly. The sediments (Carboniferous to Cretaceous), though unimportant from the point of view of areal extent, are very important topographically as they form an easily weathered foundation for the overlying lavas.

Traces of human occupation date from the time of the vitrified forts. The Norse invaders have their memorial in several place-names, but the bulk of these are Gaelic. The remains of shielings (summer dwellings) are common on the hill slopes between Loch Aline and Auliston Point. The evictions have left their mark in many deserted clachans, e.g. Auliston, Sornagan, and Allt an Aoinidh Mhòir. The uses to which the area is put at the present time include deer-forest, sheep farms, crofts, and afforestation, the last being undertaken by the Forestry Commission on ground lying W. of Loch Aline.

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Mr. W. V. Lewis.—Plucking as a factor in glacial valley erosion.

The surface of contact between the ice and rock at the head of the Jungfraufirn was examined in a tunnel, and although the site was above the bergschrund the ice was plucking the rock wall. Large blocks were separated from the rock face by as much as a foot of ice and numerous smaller pieces were partially or wholly split off, and layers of ice occupied the cracks. Similar frost shattering could take place

at great depths beneath glaciers provided (*a*) melt-water is available and (*b*) it can subsequently freeze. Temperature measurements on glaciers indicate that more than 20 metres below the surface the temperature of the ice is everywhere at the pressure melting point. This value falls $0 \cdot 1^\circ$ C. for every 500 ft. of ice so that temperatures at considerable depths are fractionally below 0° C. Thus small quantities of melt-water reaching great depths might freeze provided the pressure is slightly relieved, and so limited frost shattering might occur. The beds of British glacial valleys, especially in their upper portions, frequently reveal steps and other evidence of glacial plucking. Ice-falls near the heads of Icelandic and Swiss glaciers indicate the presence of similar rock steps below. Frost action probably also occurs at the sides of glaciers leading to the characteristic U-section of glacial valleys.

The benches in the sides of Alpine glacial valleys are attributed to the sapping action of elongated masses of ' bench ice ' perched above the level of the main glaciers.

THE FUTURE OF FLYING

ADDRESS TO SECTION G.—ENGINEERING

By H. E. WIMPERIS, C.B., C.B.E., Hon. D.Eng. (Melb.), F.R.Ae.S.

PRESIDENT OF THE SECTION.

The Presidential Address to the Engineering Section of the British Association provides each year an opportunity for a survey of some aspect of engineering science which happens to be of especial importance at the time it is given, and often one which the experience of the President of the hour may chance to render especially appropriate. My subject to-day is ' The Future of Flying.' Of its importance at the present time there can assuredly be no doubt. Aviation is surveyed by the public with a tempered pride—Pride, it is true, in man's achievement, but Apprehension, it is equally true, as to the use which is being made of it.

The aspiration towards winged flight was expressed, I submit, with great wisdom when, more than two thousand years ago, the Psalmist avowed his longing for ' wings like a dove ! ' How wise a discrimination is revealed by the poet's asking not merely for the power of flight but that his wings shall be ' dove-like.' For the space of a generation mankind has possessed the power of flight—a marvellous scientific and technical triumph but, alas, incomplete. Brilliant as was the work of the brothers Wright, the crown of achievement will not be truly won until a grateful mankind sees that the wings gained are the wings of a dove and not those of a bird of prey.

This is the challenge to our age. One generation has solved the mechanical problem, leaving it to the next to solve the moral one.

Ever since man inhabited the earth he has lived not by his physical powers, which are slight, but by the exercise of his wits. Every new invention he has made has had its warlike use as well as its peaceful purpose, and each has challenged his wits to ensure that good rather than harm shall result from the

new discovery. To bend the newest invention of all, the conquest of the air, to the service of mankind is now his great task. In it, success is essential lest we presently find that it is the air that has conquered mankind rather than mankind the air. Before we can regard the conquest of the air as achieved we must control the warlike menace.

In our own technical field, we as engineers have long been used to responsibility, to pioneer work, to expert status. But when it comes to the social application of our inventions, we are responsible not in our capacity as engineers but as ordinary inexpert citizens : and here we have been very conscious of our amateur status. We are not experts in the social application of our work ; and we are but a handful among millions. This has been the view of the last generation—though held with increasing uneasiness, as the misuse of our inventions has become more apparent.

But is it possible that the conditions which formed this view are changing ? May it be claimed—I think it may—that we as engineers, as technicians, have an important contribution to make towards the peace of the world ?

I believe that the scientific advances of the present time, and their probable development in the near future, will help us to solve, and not to aggravate, our central problem—the task Lawrence of Arabia spoke of as ' the biggest thing to do in the world to-day '—to bend the newest invention of all, the conquest of the air, to the true service of mankind.

Mechanical flight was achieved when Wilbur Wright flew in December 1903 in that odd-looking machine now so proudly housed in the Science Museum at South Kensington. It certainly does look a queer machine to modern eyes. Although the engine weighed 180 lb. it gave but 12 h.p. ! Of course it was natural that this, like all the other early aeroplanes, should be built with two pairs of wings. Engineers were well accustomed to carrying bending moments by a form of girder construction having an upper and a lower boom, and in the biplane form of construction the loads could be carried in this familiar way. Such early trials as were made of the monoplane type merely seemed to confirm the idea that a strong wing structure could not thus be found, and the biplane became the accepted type. Speeds in those days were low, and even long after the Great War it was thought that the attainment of high speed would be mainly a matter of putting in more and more engine power. More and more power was accordingly put in. This led indeed to the achievement of higher speeds, but far-sighted designers saw that there was a limit to the extent of progress by this means. But, as a Spanish proverb has it : ' When one door shuts another opens.' The new door in this case proved to be the streamlining of the external form of the craft as a whole.

That the cleaning up of the aerodynamic structure could carry performance much further than had hitherto been realised, and do so without any increase of engine power, was first clearly pointed out, little more than ten years ago, by Professor B. M. Jones of Cambridge. This required that all excrescences should be removed, and of these some of the worst were the interplane struts and wires. When that had been achieved it was realised that much of the equipment hitherto carried externally, especially in military types, must be put inside, and with that attained, after a severe struggle, there arrived the modern streamlined aeroplane with its undercarriage, and even its tail

wheel, retractable into the body of the structure. What yet remained was attention to those external surfaces scrubbed by the passing air stream. Here guidance was given, curiously enough, by the experience of sailplane pilots, who had long found that a much better gliding angle was attainable when the surfaces were not merely made smooth, but were carefully polished, and even dusted before flight ! At the time these minutiæ of housemaid's care seemed fantastic, but experience, both within wind tunnels and without, showed that the sailplane pilots were right and that protuberances on a wing no more than a thousandth part of an inch high produced a measurable drag.

Flying To-day.

The consequence of these and other changes in design from the original Wright machine brought a steady growth in speed, which during the last score of years has increased by an average of well over 10 miles an hour in each year.

This overall increase in aeroplane performance is indeed impressive : in speed from the 31 m.p.h. of the Wrights to the 469 claimed to-day ! Behind the change in external characteristics there have been internal changes of an equally important character, such as the increase from the Wrights' wing loading of 1½ lb. per square foot to the figures of to-day when 20 to 30 and 40, and even more, are common. There has also been an equally impressive change from the modest engine power of the Wrights to the four-figure powers of modern practice.

So far as growth in altitude and range of flight are concerned, further progress must depend chiefly on improvements in the present-day materials of construction, or on the discovery of entirely new ones. At the moment dural is found best, not because it has any higher ratio of strength to density than alternative materials, for in that respect it differs little from steel, or even from cotton or reinforced plastic ; but because in comparison with steel its lower density (little more than a third) enables thicker and therefore stiffer and more fool-proof sections to be used. But, as in the case of steel construction, the sections have to be fastened together with innumerable rivets (more than a million in one 'Golden Hind'), and this time-absorbing process is both intricate and costly. If some improved reinforced plastic could be used instead, the path of the manufacturer, once he had learned the art, would be much simplified.

Speeds have grown because of the smoother shapes used in construction and through the greater engine powers provided. Can speeds continue to rise indefinitely ? We may have gone almost as far as we can in using ship-shaped forms, though we still know very little about the possibility of ensuring an increase in the extent of the laminar flow of the air over the surface of wings or body : if this could be done the resistance would drop considerably. So far as prospective increases in engine power are concerned there is little publicly revealed in these days, but one hears of testing plants being adapted to deal with engines of no less than 3,000 h.p. apiece. But even with these increases a definite speed limit is being approached—not one imposed by the laws of any State but by the laws of Nature. As I pointed out two years ago in a Presidential Address to the Royal Aeronautical Society, there is good reason to believe that although speeds of 500 m.p.h. may be attained, it is unlikely

that 600 will be much if at all exceeded, for the latter figure is some 80 per cent. of the speed of sound, and when the latter is approached the drag rises to a level far ahead of any prospective engine improvements. Although nothing in the physiology of man forbids even higher speeds, as witness the high orbital speed of the earth on which we all live with some measure of tempered comfort, there is soon imposed a physiological limit if high speed is combined with rapid manœuvre. If the latter is required then the speed must be controlled to suit the conditions. Only the future can reveal how the balance between the two will be struck.

No simple summary can be given of what has been done as regards engine development, for great as has been the change from the fifteen pounds per h.p. of the original Wright engine to the one pound, and less, of to-day, one remembers that in this one respect the engines of the last Schneider Trophy Race were as meritorious ; where the latter were much below modern standards was in their lack of reliability when working at this power ratio. To-day's engines run without attention for hundreds of hours, a very different matter from endurance for a short race.

Even if engines of 3,000 h.p. may be said to be in sight they are still some way from achievement. Progress depends not only on the skill of the engine designer and the metallurgist, but on the ingenuity of the industrial chemist in producing his remarkable fuels, wonderful alike for their uniformity of quality and for their ability to resist detonation even when employed in engines of very high compression ratio.

The outstanding constructional change to-day is the employment on a large scale of the sleeve valve, particularly as developed by the great Bristol firm. This has the impressive merit of only needing half the component parts of the old type poppet valve engine ; moreover it is found that, with a given fuel, it can operate without detonation at an appreciably higher compression.

Engines to-day run safely at far higher speeds than of yore, and they are cooled in different ways and at a much less expense in air drag than used to be the case. In fact at the highest speeds the drag offers some theoretical promise of being replaced by a small thrust ! A new cooling problem will arise, however, when pusher airscrews become as common as they will once their use is shown to afford a means of substantially decreasing wing drag.

Improvement in load carrying capacity depends also on improvements in materials, though it is fair to designers to record the progress made in reducing the percentage which the structure forms of the total flying weight in modern aircraft. Nowadays as good a figure is shown for this in large flying-boats as in landplanes, a remarkable achievement. The flying-boat used to be thought of as slow and heavy, but to-day it holds its own, in efficiency, whether aerodynamic, structural, or economic, with any other mode of flight.

The flying-boats of to-day represent a great technical advance in quality over their predecessors of ten, or even five, years ago, but they have not yet shown any marked advance in size. The fine fleet of Empire flying-boats is made up of 20-ton units ; the new Short 'Golden Hind' class for the Atlantic weigh 33 tons apiece ; the Boeing 'Yankee Clipper' has a total weight of nearly 40 tons ; but the Dornier Dox which long preceded them ran to 50 tons laden. On the other hand there has been a great gain in speed and in carrying capacity. The Boeing boat, for instance, is reported to carry

10,000 lb. of load over and above its 4,000 gallons of fuel : as this amount of fuel will weigh 30,000 lb., this makes a total load of 40,000 lb., or almost exactly half of the total flying weight, the same as for the 'Golden Hind,' and a truly remarkable percentage. The improved Empire flying-boats intended for the Atlantic crossing are planned to take-off at a flying weight of about 20 tons and to take 3 tons of additional fuel after they are air borne—by supply from a flying tanker on Sir Alan Cobham's scheme : this will increase the load on the wings from 30 to 35 lb. per square foot and may be regarded as a first step towards what could be done with wings specially designed and stressed for high loading. The 'Golden Hind' class is designed for a range of 3,400 miles without refuelling, and this with full load. Its early programme may include a survey flight along the route to Latin America.

An attractive development in flying-boats is the provision in the Dornier DO.26 of retractable wing-tip floats which fold inwards into spaces in the wing. This is a 20-ton machine with two tractor and two pusher airscrews. It is a promising move in a very much desired direction. The remaining structural feature to be made aerodynamically clean is the 'step' at the hull provided for ease in taking-off. It is no doubt difficult so to design a hull as to be equally efficient whether on the water or in the air, but designers will not be happy until they have satisfied both requirements.

It is naturally impossible in the course of this address to discuss all the many problems in the science of aeronautics which are being investigated at the present time. They are far too numerous and the time too short. But to some of them I must refer. One of great importance and quite fascinating interest is the investigation of the change in the air flow over a wing surface from the laminar to the turbulent state. It is known that if the flow could be kept laminar the drag would be vastly reduced, but it has yet to be discovered how to do this. A step in the right direction may lately have been made at the Langley Field Laboratories, for during Dr. Lewis' recent Wilbur Wright lecture before the Royal Aeronautical Society mention was made of some wind tunnel tests in which a special form of aerofoil gave a drag coefficient figure of only about one-third of that usual. Further particulars will be awaited with interest. Many laboratories and experimental stations are studying this same problem, and, as not infrequently happens in such cases, success once met with, itself creates a batch of new problems. For one thing it is clear that the presence of laminar flow can but be hindered by the use of the tractor type of airscrew now almost universal. It may be necessary to change to pusher designs, and as this will involve a marked rearward movement of the centre of gravity of the whole aircraft, all the stability factors will be gravely affected, to say nothing of the many engine problems also raised.

Other special problems relate to the possibility of having wing areas adjustable in flight by telescopic or other means, to the study of the very considerable increase in the control forces required of the pilot in large machines of high speed capacity, of the special problems raised by variable pitch airscrews, particularly in relation to the landing run, of the advantage at high air speeds of two-speed gear boxes, and of the special problems involved in pressure cabins.

The problem of the rotating wing is in a class by itself. Aircraft so fitted

are quite unable to compete in speed with those with normal wings, but they easily beat the latter in take-off and landing. Many types are now in the field, the Cierva, the Hafner, the Kay and the Focke, to mention no others. The scientific problems are largely solved, as are the great mass of the mechanical ones. What is required is such a degree of user as will call for this form of aircraft to be constructed in numbers. When that happens rotary wing aircraft will benefit in their design by that skilled attention from the production engineer which alone seems able to produce results that really look right !

The growth in recent years of the interest taken by the public in aviation, over land and over sea, is most striking. Partly, of course, it is due to the increase in the Air Arm and all that is thereby implied. But there is also a very rapidly growing use being made of the abundant facilities for air travel offered by the Civil air transport services. The United States is often thought to lead the world in this respect—as it certainly does in the use of the automobile—but I believe that in proportion to the size of the population, and that is the true criterion, the total mileage flown annually is larger in Australia than it is in any other single country in the world. And there is good reason to expect that that pre-eminence is likely to continue.

The Future Years.

Let us consider what lies ahead in the coming years in respect of speed, size and range. No doubt military craft will go as fast as they can. But since it seems that they cannot exceed 600 m.p.h. much if at all, there is little doubt that speeds between 500 and 600 will become usual. Not so, however, for the Civil Air Services, where quiet, comfort and cost are all-important : here there is good economic reason for speeds to settle down in the 200 to 300 range. In both these classes we seem therefore to be approaching some degree of finality.

Altitude and range are alike in that so much depends on the discovery of new materials of construction and new ways of using them. Steady progress may be expected, though probably nothing sensational unless the use of reinforced plastics be so reckoned. For civil work the advantage of long-range flying depends on the ability to fly by night, and this is advancing rapidly. Radio services are improving and the vagaries of the ionosphere are becoming better understood. High altitude flying—whether in the stratosphere or just below it—requires the sealed cabin, and it will, I fancy, chiefly be sought by those whose first care is speed and whose lesser concern is cost.

When, however, we come to think of such other factors in the future of flying as the size of the craft, and the wing loading employed, we are concerned with quite other considerations. Size depends mainly on engine power, for there is a limit to the numbers of power units which can be conveniently looked after. Even if we have tractor and pusher airscrews in tandem (and tractor screws may well become unpopular where the highest aerodynamic efficiency is sought), six such pairs may be the practicable limit. This would give us twelve engines, which, at 3,000 h.p. apiece, makes the total power 36,000. At 15 lb. carried per h.p. available this would give a total flying weight of 540,000 lb. or some 250 tons. Such a craft would naturally be a large boat, taking 200 passengers or more ; and that is the largest flying craft that can be

said to be now in sight, although I ought perhaps to mention that in a lecture to the students of the Royal Aeronautical Society, who alone perhaps might be expected to live to see it, Dr. Roxbee-Cox was bold enough to include an American forecast for a boat of 3,120 tons ! But difficult as it may be to foretell accurately the future of the large flying-boat, there can be little doubt that we shall soon see such craft in active competition with their older rivals—which use the surface of the sea—for all rapid passenger transport on the important Atlantic routes.

The future of wing loading is hard to forecast. As has been mentioned, the early Wright aeroplane was loaded to 1½ lb. per square foot. By the time of the Great War this had risen to the neighbourhood of 10, but even Hallam ('Pyx'), writing as prophet a few years later of his vision of a 200-ton flying-boat, did not put it above 8 ! In the succeeding years, however, the figure has grown gradually until it is now in the neighbourhood of 30 ; and while loadings of 40 to 50 are talked about for future craft, Sir Alan Cobham has suggested that, provided the bulk of the fuel is added by refuelling in the air from a tanker, loadings as high as 60 or even 70 should not be unattainable. The real limiting factor here is the take-off and the landing. With landplanes, the disadvantage of high loadings is that they lead to great increase in the size and cost of aerodromes, unless this can be avoided by the use of an auxiliary like the Mayo Scheme or by some form of catapulting, or by the use of the 'tricycle' undercarriage, now so rapidly coming into use. This consequence of high loadings does not apply in the same degree to the flying-boat, but even there it has the disadvantage of requiring the use of natural harbours of large size with not too much local water traffic.

Can one, however, relate these speed ranges of 500 to 600 for military craft, and 200 to 300 for civil, with wing loading, with or without refuelling in the air ? We have the relationship that the minimum air speed of flight is measured by the square root of the wing loading. If we assume the use of such aids as wing flaps, we can calculate for sea-level conditions just what the stalling speed for any given wing loading must be.

For a take-off speed of 100 m.p.h. (i.e. stalling speed of 80) the wing loading would be about 40 lb. per square foot, suitable for civil types having a top speed of, say, 300 m.p.h. (since the take-off and landing speeds would then be about 100). But once in the air a much larger load could of course be carried.

In the case of military types having top speeds of 550 m.p.h. or thereabouts, the landing speed could hardly be less than 150, giving a wing loading of 100 lb. per square foot. It looks therefore as though in the coming years the wing loadings for civil types will go little beyond what is now planned in many drawing offices, but in the case of military types the present-day figures may certainly be doubled unless some new wing arrangement can be discovered which will greatly reduce the loading figure when a landing is about to take place. Rotating wings are the perfect solution for the landing problem, but how to combine them with means for the attainment of high horizontal speed is a problem which the future has yet to solve. The one recent development—or revival—which seems to promise a great advance in safe landing is the tricycle undercarriage : the use of which seems to be almost all pure gain. In a lecture before the Royal Aeronautical Society last year Mr. H. F. Vessey

expressed the rather conservative view that although with landplanes of the normal type it is difficult to see any considerable increase in wing loading at landing above about 30 lb. per square foot if present restrictions on landing distances over a barrier are to be maintained, nevertheless he admits that by the use of the tricycle undercarriage the loading might go as high as 40.

It is odd that chance should decide—or perhaps appear to decide—the future of so many forms of human activity. Almost at its birth, broadcasting fell into good hands, and the cinema into bad, but aeronautical research, very fortunately, into good. I can imagine a critic remarking that it was not quite all chance : that broadcasting was preserved by the Post Office control over radio, and that organised aeronautical research owed everything to the wise foresight of the late Lord Haldane, who caused there to be created an Aeronautical Research Committee with funds for research workers and apparatus for them to use.

Fortunate it was indeed that research in aeronautics was so wisely led and adequately supported. It was a new science, and one of the few happy results of the Great War was that it drew into this service some of the most brilliant young scientific men of the day, especially from the universities of Cambridge and Oxford. And this interest held, for even now the leaders are largely drawn from that band of pioneers. In their early work they were happy in their hour, for almost anything that was done was necessarily original and almost any invention was bound to be new : there was little need to consult the records of the past. The Aeronautical Research Committee was, and still is, mainly drawn from these men and those they have trained. With the support and confidence felt in them by the Government, they were able to develop ideas, whether arising from their own ingenuity or from workers and industrialists outside. It was an example soon copied by the United States, and its latest adherent is Australia, the newest country to take up aeronautical engineering as a serious national effort.

It is impossible not to be struck by the stimulus which this specially directed scientific research work has given to other branches of engineering. It represents the spearhead of attack in applied science, since so many of its problems arise from practical conditions of unusual difficulty, owing to the intensity of the desire for light construction combined with strength and durability, and for very high efficiency factors. It is hardly surprising therefore that such apparently non-aeronautical fields as the design of steam turbine blades, of power boats, of industrial fans, of light vehicles should owe so much to the results of aeronautical research.

The Air Arm.

Among the world's many political preoccupations there is no more pressing or more intractable problem than that of curbing in some way the universal growth of armaments. It is true that in so far as the product is entirely produced within the country of origin the mere cost is of little moment. One makes armaments instead of making something else, and in the case of a people who loved above all having lots of lethal weapons there would be nothing more to be said, though the taste might be thought odd !

It is not, however, solely a matter of finance, since normal peoples would much prefer the energy directed to armament production to be given to articles of service in civil life such as houses, pictures, sailing-boats, holiday camps and the like ; and for the general body of such activity to be guided into channels which fit in with the quantity and quality of the labour available in the country. Moreover, just as a house containing a store of high explosives is not looked on as a happy abode, so there is always a fear that in highly armed international life a trigger in some remote spot may be pulled by accident, or by mischief, with irreparable harm to the whole world.

When some years ago an effort was made to come to an international understanding about air armaments, success was not attained. This was due, it is true, in some measure to the existence of strong professional interests and to the relative lack of attention to the needs of the ordinary man, but it was partly due to the inherent difficulty in the then state of the art of distinguishing between military and civil types. Even suppose, it was asked, that one could abolish all military aircraft, how would one deal with the civil types which could be so easily converted ? In those days this was a germane question. But is it now ? I think not, and for this reason.

The speeds of military aircraft are now in excess of 400 m.p.h. and will rise still higher. But civil aircraft rarely go faster than 250, and it is doubtful whether it is economically advantageous to have even so high a speed as that. This at once makes a great difference in the types. Again, the comfort and space needed for civil transport tends to produce a design of body which does not in the least resemble military requirements. In so far as the civil types in their really large sizes come more and more to take the flying-boat form, so are they the less like military types. Perhaps I should say here that I am leaving aside reconnaissance duties and troop-carrying, and thinking mainly of the aggressive type, the bomber.

Hence I submit that, as I suggested in a recent address at Chatham House, the position has been reached when, so far as technical considerations are concerned, an agreed limitation could be set on military production without the effort being nullified by the existence of civil types to which no such limitations applied. It must be remembered, however, that when a political man talks about ' parity in the air ' he may not really understand what he is saying. What he probably means is equality in offensive force, for mere parity in numbers might be got by the absurd equation of putting 100 bombers plus 1,900 interceptor fighters as equal to 1,900 bombers plus 100 interceptors, because both sides add up to 2,000. It cannot worry any peace-loving country, if one of its neighbours builds 1,000 or 10,000 interceptor fighters, any more than it would if that neighbour built immense numbers of anti-aircraft guns and searchlights. In fact, as a gain to the general strength of defence it would be rather comforting than otherwise.

The right way to arrive at a proper balance of air armaments is to seek reasonable parity in respect of bombing aircraft and leave everyone free to build as many defensive aircraft as they care to afford. Civil types would by reason of their low speed be incapable of acting as fighters, and would be speedily shot down if they tried to act as bombers.

There has recently been translated from the German a striking book by S. T. Possony under the title *To-morrow's War*. It is rather difficult to follow,

partly no doubt because it is a translation, but the author's object is to show what would be required in respect of men and materials for one year of war of the ' total ' variety. He assumes a front of 1,000 kilometres, and he arrives at some astonishing figures. He points out that although the losses of aeroplanes in the Great War were but 14 per cent. per month, he anticipates that in a war to-day the monthly loss would rise to 25 to 30 per cent., calling for complete replacement of the whole air force three or four times in the year. For this war Possony estimates a requirement per annum of no fewer than 70,000 bombers and 130,000 other aeroplanes, or 200,000 in all. He then claims that hardly any State could man at one time more than 10,000 to 20,000 aeroplanes and tanks, on account of the exceptional types of men needed and the exceedingly heavy losses. For this and other reasons he concludes that ' decisive war is most improbable.' He agrees that the world has entered on an era of wars with limited objectives, undertaken with limited means, an era of camouflaged, undeclared wars, the reason being that the nations engaged, being determined not to open the fatal door which leads to universal disaster, seek thus a possible means of achieving their ambitions. Success in a sudden sharp war he thinks impossible. All ' total ' wars are bound to be long ones. These arguments, if they are acceptable, certainly suggest a pause in the world race to build up huge armaments. The only sure result is financial embarrassment in what should be days of peace, days in which there are so many better things to be done with one's money.

The discovery of the art of flight has certainly raised terrible problems, but it does at last seem as though mankind is beginning to see his way out of the morass. That the laws of Nature impose a speed barrier is a fortunate thing, for that suggests some finality to the development of types, and limits, moreover, any uncomfortable rivalry with the speed of response of the human body. It is fortunate, too, that this speed limit is much above the economic limit for civil machines, for that means that the civil type can easily be defeated if it tries to play the corsair. And it most blessedly happens at the same time that the strength of anti-aircraft defence from the ground and in the air is increasing in effectiveness at a rate that even the most optimistic had hardly dared to hope. Britain, an island in the sea, will become an island in the air !

In my view there will be no reason, once the international situation has cleared, why there should not be an agreed limitation in respect of numbers or tonnage of bombing aircraft—leaving the interceptor fighters entirely aside. It would be but cautious to agree on a limit to the speed of civil types, but as this would merely confirm what economic requirements would themselves suggest, it need be no hardship ; excessively high speeds for civil types do not pay, are much more dangerous to passengers, are much more noisy to everyone, and need wasteful forms of air ports.

When this difficulty of our own age has been at last happily solved, we may be very content to leave our successors the even more threatening menace of dealing aright with the problem of atomic energy. This it is not necessary for me to describe. I will only say that in a recent broadcast address Prof. Cockroft spoke of an atomic trigger action between the metal uranium and a single neutron which is reported to be capable of releasing a 100,000,000-fold increase in energy ! Perhaps there are immense practical difficulties in doing this on a large scale ; I earnestly hope there are ! For ourselves we may well

consider that in our own day we are quite sufficiently occupied with the thoughtful handling of our own special problem, how rightly to guide the Future of Flying.

SECTION G.—ENGINEERING

NOTE ON COMMUNICATIONS

No abstracts of communications to Section G have been printed by the Association, but the practice of several years' standing, under which such communications have been published in *Engineering*, has been maintained. The following papers, which were or should have been read at the Dundee Meeting, have been published in that journal, in addition to the president's address.

'University Engineering Courses,' by Prof. W. Jackson.
September 8, 1939, p. 288. Discussion.
,, 8, 1939, p. 292. Paper.

'The Design of Roads,' by R. G. H. Clements.
September 8, 1939, p. 289.
,, 15, 1939, p. 309. Discussion.

'The Trans-Atlantic Air Service,' by Major R. H. Mayo.
September 15, 1939, p. 309. Discussion.
November 10, 1939, p. 541. Paper.
,, 17, 1939, p. 565. ,,
,, 24, 1939, p. 594. ,,

'The Mechanics of Towing Road Vehicles," by R. Borlase Matthews.
September 15, 1939, p. 312.

'The Voith-Schneider System of Propulsion,' by Capt. E. C. Goldsworthy.
September 15, 1939, p. 315.

'Simple Models for the Study of Engineering,' by Prof. Frederic Bacon.
September 22, 1939, p. 341.

'Ignition Lag in Compression Ignition Engines,' by S. G. Bauer.
September 29, 1939, p. 368.

'Non-Linear Distortion in Iron Testing,' by Dr. James Greig and Ernest Franklin.
October 6, 1939, p. 395.

'The Inductor with Air-Gapped Magnetic Circuit,' by E. V. D. Glazier.
October 13, 1939, p. 406.

'The Flow of Liquids through Beds of Granular Solids,' by William H. Ward.
October 20, 1939, p. 435.

'Air Furnace Melting for Blackheart Malleable Cast Iron,' by H. G. Cochrane.
October 27, 1939, p. 484.

'The Stressing of Rotating-Blade Aerofoils,' by J. B. B. Owen.
November 3, 1939, p. 511.

PRACTICE WITH SCIENCE

THE FARMER'S POSITION AND THE SCIENTIFIC WORKER'S PROGRAMME

ADDRESS TO SECTION M.—AGRICULTURE

BY

Sir THOMAS MIDDLETON, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S.

PRESIDENT OF THE SECTION.

When, in 1912, Section M held its first meeting, my Presidential Address was upon the early improvers of husbandry, and I referred especially to the assistance given to agriculture through the societies and associations formed by them for promoting experiments and discussion. Section M was the latest addition to associations of the kind and we who were then present looked forward with expectation to the benefit agricultural science would get from the formation of the new section. In spite of the calamity of the Great War and the unrest in the world which has since developed, I feel sure that all of us here, in returning to Dundee where that first meeting was held twenty-seven years ago, will agree that the hopes then formed have been more than fulfilled by the progress of Section M.

My survey in 1912 ended with the decade 1831–40 which saw the birth both of the British Association itself and of the Royal Agricultural Society of England. For the title of my address to-day I have taken the familiar motto 'Practice with Science' which the Society adopted at its formation one hundred years ago; I have ventured to do so without permission and for this I apologise to my fellow members. The motto was selected by a group of pioneers intent upon improving English farming at a time when the industry was in a difficult position; the applications of science to practice were just beginning to attract general attention and the motto tersely proclaims the intentions of the new society to combine with the practice of its members all the new knowledge which was then becoming available.

The progress made by agricultural science in the past hundred years formed the subject of Sir John Russell's address to Section M when the Association held its Centenary Meeting in 1931, and a second review after so short an interval is uncalled for. My purpose in selecting the motto 'Practice with Science' is not, therefore, to use it as an occasion for a review, but so that I may refer to matters affecting the present circumstances of both partners in the motto. The existence of Section M is in itself a proof of the large amount of scientific work now being carried out on behalf of agriculture and also of the interest which the scientific public take in the subject. Although it has many shortcomings, as the workers concerned will be the first to admit, it may be claimed for agricultural science that it has prospered and is prospering;

in contrast, everywhere there is evidence of the difficulties of agricultural practice.

In our motto practice and science are linked for a definite purpose, and if the link fails, so that one of the partners falls behind, the progress of the other partner is inevitably affected. I propose, therefore, in the first place to draw your attention to the farmer's position and to attempt an explanation of his difficulties, and later to refer briefly to certain sections of the scientific worker's programme which, in present circumstances, call for attention.

I.

Those who, last month, visited the Centenary Show of the Royal Agricultural Society of England and took the opportunity, then given, of contrasting some of the implements formerly at the farmer's disposal with the modern machinery and implements displayed in Windsor Great Park, must have been impressed with the extraordinary change which the skill of the engineer has brought about. Those, too, who through descriptions and pictures know something of the character of farm livestock in 1839, would be equally impressed by the improvement which, in the interval, stock breeders have effected in farm animals. But while inside the Show Ground every exhibit told of progress and of the great resources now at the disposal of the agricultural industry, those farmers who journeyed to Windsor by road would not lack evidence that all is not well with land management; far too many fields would be passed of which no farmer could feel proud. It is indeed undoubted that there is in the country much land at the present time which is less productive than it was a century ago, and the progress of the industry in the interval has certainly falsified many hopes then formed. For evidence of these hopes one might turn to the agricultural journals of the time, in which articles pointing to the possibility and prospects of improvement appeared; but an independent witness may be cited. Porter, in his *Progress of the Nation*, pointed out that between 1801 and 1841 the population of the United Kingdom had increased from 16¼ to 27 millions, or by 1⅝ per cent. per annum, and that as a result of progressive applications of capital to the land, the production of food had increased at an approximately equal rate. Porter was a strong free trader and, when writing the preface to the second edition of his book in 1846, just after the policy he had advocated was adopted by the country, he refers to the past achievements of agriculture and remarks 'there is reason for believing that we shall see far greater results from the same cause in future years. . . . It would indeed be difficult to show why when an equal degree of skill and energy and a greater amount of capital are employed in the *manufacture* of wheat our farmers should not be able to undersell the foreigner, as we now are able to undersell him in manufactures of cotton and hardwares. This question must shortly now be put to the proof and I for one have no misgivings as to the result.'

Porter's 'question' has been answered, but not in the way he expected. I have shown elsewhere [1] that during the decade 1831–40 the land of Great Britain maintained a population of about 17 millions; it now provides food

[1] *Food Production in War.* Clarendon Press, Oxford, 1923.

for about 14 millions, and this although farmers of to-day have available, as their predecessors had not, artificial manures, first-rate implements, improved varieties of crops and all the assistance which a century of scientific study has given to agriculture.

Although it is an easy thing to criticise much of the farming one sees to-day, it would be unjust to fix responsibility for the farm's condition upon the occupant of the farmhouse. All who are in contact with the industry know that, in the post-war period, rising costs and uncertain prices have so crippled the resources of the farmer that he is quite unable to bestow on his land the same careful treatment that it got from his forefathers ; and no one regrets its condition more than does he himself.

The extraordinary weather of 1938 brought farmers' difficulties to a crisis and in recent months agricultural policy has engaged closer attention than in any time within memory. It is not my place to discuss Government policy ; but in the course of the arguments which these political questions have aroused there has been shown a good deal of misunderstanding of the farmer's position, and my immediate purpose is to try to explain his handicaps. In agricultural circles all the matters to which I shall refer are familiar topics ; but to the public the unhappy position of the British farmer, with the world's best food market open to him, must often be a mystery ; a mystery which is not infrequently accounted for by the phrase with which *The Times* newspaper begins its annual review of agriculture in 1938, 'Grumbling is said to be the farmer's privilege.'

What is there to grumble at ? Let me illustrate by a reference to Scottish experience.

Nine years ago the Department of Agriculture began the issue of a series of annual reports termed 'The Profitableness of Farming in Scotland.' The figures required for these reports are obtained by the Advisory Economists of the Agricultural Colleges, who collaborate with the Department's officers. Very full information is obtained, the records are carefully analysed and the completed reports are informative and very interesting. Conditions in all parts of Scotland have been surveyed. My own special interest is in the north-east, which is my home land. In these reports the farms of the north-east have been arranged in groups. I select one of them, which in the first five years was Group 1 and has since been Group 2. In general terms the farms included in my group may be described as consisting of moderately large holdings of about 450 acres, with from 325 to 375 acres under the plough. Rents are rarely less than 17*s.* and rarely more than 20*s.* per acre. The tenants' capital is about £10 per acre and the saleable products consist mainly of fat cattle and sheep, oats and potatoes. The number of farms in the group referred to has varied from ten to twenty-two.

In assessing profits the practice is to charge the occupier of the farm with an appropriate rent for the house which he occupies ; he is also charged with the value of the produce consumed in his household. When these adjustments have been made I find that over the nine-year period the farms in question showed an average return on tenant's capital of 7·7 per cent. In this figure there is included the farmer's remuneration for his own work. If a charge of 4 per cent. is made for interest on capital, then the farmer may be said to earn a salary of £140 per annum. In the best year of the nine the farmer's income

rose to £600, after charging interest at 4 per cent., but in the worst it fell to *minus* £288. It is no wonder that after the calamitous harvest of 1938 these north-eastern farmers should have besought the Secretary of State for Scotland to visit the district and to see for himself the plight to which they were reduced.

The Department's accounts extend over a period of nine years only and do not enable us to contrast pre-war and post-war conditions. It happens that I have had access to some farm accounts which, though not so detailed as those of the Advisory Economists, enable this comparison to be made. I shall refer in the first place to the post-war accounts of a farm very similar to those in the group mentioned above. For the first three years after the war the Profit and Loss statements were so much affected by the writing down of inflated values that I omit them. There remain, until May 1938, accounts for fifteen years which, after adjusting for house rent and value of produce consumed, show an average profit of 6·9 per cent. on the capital invested. If 4 per cent. were charged on the capital a salary of £2 per week would remain for management.

Until 1919 the farm in question formed one of several, managed on similar lines, for which accounts are available from 1872 onwards. In two years only in the forty-eight years to 1919 did a balance appear on the wrong side and in neither year was it a large one. In six of the above fifteen post-war years the balance was on the wrong side. The returns per acre over the worst fifteen-year pre-war period were about 10 per cent. better than the returns of the fifteen-year post-war period, while between 1872 and 1919 the returns per acre were about 75 per cent. greater than they were in the fifteen years ending in May 1938.

Dairy farmers in the south-west of Scotland have fared much better than farmers in the north-east, as dairy farmers have done elsewhere, milk prices being at a much higher level, in comparison with pre-war prices, than in the case of other farm produce. Recently, too, the Milk Marketing Boards have ensured producers of a market. But throughout the arable districts of Britain the experience of farmers has not differed widely from that to which I have alluded above.

In a recent report of a Cambridge survey made in the eastern counties it is stated, for example, that 'in only one year since 1931 have these surveys suggested that there has been on the average any appreciable surplus over and above interest and occupier's wage.' In 1938, when the Cambridge survey contained records of 200 farms, of the average size of 163 acres, in the counties of Norfolk, Essex and Cambridge, it is shown that, when credited with house rent and produce consumed and debited with interest at 4 per cent., the farm income sufficed to pay the occupier a wage of no more than £100 for his year's work; adding interest at 4 per cent. on his capital of £1,765, the average farmer had at his disposal an income of £171, out of which he paid £53 for house rent and the produce consumed by his household.

Although in the post-war years the British farmer has had a very hard time his trials have been nothing like so great as have been those of farmers in the United States. In the later war years farmers in the States enjoyed great prosperity, the gross income from American farms rose from an average of about £1,428 millions in the three years 1911–13 to £3,600 millions in 1919–20; there was a very heavy fall in 1921 and 1922 and then, although there

was some recovery, a difficult time continued until 1929 ; after the financial crisis of that year there was a catastrophic fall, so that in 1932 the farmers' gross income was estimated at £1,132 millions or less than one-third of the amount at which it stood twelve years before. The American farmer depends much less on hired labour than does the British farmer, and in the depth of the depression he not only dismissed many workers, but reduced wage rates, so that in the years 1932–35 they fell from 11 to 12 per cent. below the 1911–13 average, but in spite of these wage cuts and every other economy the farmer's plight in the early thirties was deplorable. In 1929, after meeting necessary outgoings and allowing themselves wages at the same rate as their hired men, American farmers retained enough to meet an interest charge of 3·3 per cent. on their invested capital. In the three following years the returns on their investments were — 0·7, — 2·8 and — 4·2 per cent. respectively.

The American farmer's purchasing power is relatively a much more important matter for American industry than is the British farmer's for our own industrialists, and towards the end of the 1920's the fall in the farmer's purchases greatly alarmed American Big Business. In 1929, a few months before the Wall Street crisis, President Hoover created a Federal Farm Board to endeavour to assist farmers by promoting orderly marketing, by encouraging co-operative societies and by checking speculation. The Board, which consisted of nine experienced and successful business men, was provided with a revolving fund of 500,000,000 dollars, from which, among other purposes, advances were made to keep surplus products off the market ; but after the crisis assistance, even on the grand scale which the Board was enabled to offer, proved of no avail ; very large losses were incurred as a result of its transactions and with the change of President it ceased to function.

When, in January 1917, I took the nucleus of the Food Production Department from Whitehall Place to Victoria Street a colleague suggested to me that for our telegraphic address we should register 'Growmore.' The suggestion was at once acted upon and when, after the war, the Food Production Department returned to Whitehall Place, 'Growmore' was adopted by the Board as a telegraphic address, so that it still remains as the Ministry's address and its slogan. But this was not the policy that leading business men in America could recommend to distressed farmers. In November 1930 the Federal Farm Board issued a leaflet with the title 'Grow less, Get more' and the sub-title 'Millions of dollars and hours of work are lost by over-production.' And it must have been sound counsel, for, though it was Republican advice, it was held to be good by the Democrats who soon afterwards came into power. From a pamphlet, 'Achieving a Balanced Agriculture,' issued in 1934, and prefaced by a message from President Roosevelt, I take the following telling lines :

'*Surplus Food on Farms—Idle Men in Cities.*—In the fact that farmers were less and less able to buy the things that people in the cities were making, lies the explanation of how one surplus caused another, until farmers were burning wheat while bread lines lengthened in the cities, until the fantastic spectacle of poverty in the midst of plenty traversed America like a dance of death.'

It was this fantastic position that led to the Agricultural Adjustment Act, which provided for the reduction of the farmers' chief commodities under a contract system ; those producers who contracted for smaller areas of certain

crops, or for keeping fewer livestock, received ' benefit ' payments by way of compensation.

President Roosevelt's Administration was one only of a number of Governments that resorted to similar drastic measures to dispose of surpluses. In South America Brazil burnt its coffee. In Europe Holland reduced its pig population by one-third between 1932 and 1936; it also slaughtered about 200,000 surplus cows, and sold the meat at low prices to the unemployed. Denmark, too, reduced its dairy herd, and took the opportunity of killing off not only old animals but tuberculous cows, thus effecting an increase in the quality of its remaining livestock. Before 1932 the Danish pig population had increased rapidly, farmers attempting to maintain their income when bacon prices fell by producing more. Our own bacon policy led the Danish Government to decree a drastic reduction in pig-breeding, so as to reduce exports to the limits set by the quota we allowed. The result was that the Danes sent us less bacon, but got more money for it. New Zealand had an opposite experience. She sent us more lambs, but secured a smaller total payment.

The extraordinary measures which the Governments of many countries have been forced to take for the protection of primary producers in recent years were due to exceptional conditions which owed their origin to the disturbance of the Great War; but in a less acute form these conditions have long existed and are now reflected in the low earnings of agricultural workers. The Agricultural Committee which met under the auspices of the International Labour Office last year to examine the position of peasants and agricultural workers reported that, in all of the twenty-three countries which were represented, the conditions of employment and the earnings of agricultural workers urgently called for improvement.

In this country, where conditions are better than in most others, workers are rapidly leaving the land to seek higher wages in new occupations and farmers, though they may be willing, are unable to pay their men what they admit them to be worth.

It is a strange thing, surely, that these conditions should exist, so that the chief of the world's many industries, that which supplies man's primary need, that, too, in which most of the world's inhabitants are engaged, should earn for its workers so meagre a reward. One reason, indeed, for agriculture's position is that among industries it is not only the most essential, but was the first. Until there was a surplus of food no other industry could arise and until that surplus was secure no other industry could prosper. Men deserted agriculture when opportunities of a better livelihood in other industries arose, and men in the mass not being given to altruism, so soon as better conditions were secured by themselves they took measures to safeguard their food supplies, regardless as a rule of the fate of those left behind on the land. The development of urban industries called insistently for cheap food, a prime factor in the cost of production whatever may be the finished product of the factory, and so gradually by organisation within industries and the adoption of methods not applicable to agriculture, better profits than could be made by food production were secured for masters and better wages for men.

In some countries, notably in our own, humanitarian motives supported industrial demands until food came to be regarded as a commodity apart

from all others, something that of right belonged to 'the people,' i.e. to the non-agricultural consumer, rather than to those whose labour produced it. I am not here concerned, however, with motives or with the justice of the treatment which food producers have received ; my purpose is to try to explain how it is that two-thirds of the world's inhabitants, those engaged in agricultural pursuits, have in the struggle for existence been reduced to a lower standard of living than the one-third who have taken to other industries. In the case of the peasant and the hired land worker, to whose unhappy condition in many countries the International Labour Office has recently drawn attention, the causes responsible are of a kind which hitherto have proved to be inseparable from a state of advancing civilisation.

To a degree varying with the extent to which the farmer depends for his reward on labour, or on the management of labour, the above-mentioned conditions affect him as they do the land worker ; but in the farmer's case there is a further circumstance which, arising about a century ago with the development of transport, now affects him acutely, because of the way in which the great food markets are closely linked by steamships, rail and road. And here it is not a case of the enlightened self-interest of his fellow-men protecting themselves at his expense that the farmer has to complain of. It is his own action which gives him a weak place as a competitor in the world's markets.

The disastrous effects of surfeited markets on the American farmer have already been alluded to, and to the effects in other countries I shall refer later ; but first let us see how these difficulties arise.

The universal demand of the consumer, i.e. of everyone including the farmer himself, is for an abundant supply of good food ; this is the demand which world markets transmit to the producer ; this is the demand which he seeks to meet and it determines his policy in planning the cultivation of his land. But unlike the manufacturer, the agriculturist cannot estimate his output closely, he knows that unfavourable seasons must be reckoned with, and, grumbler though he may be at harvest time, the farmer is always an optimist in the spring. This constitutional optimism, be it noted, is a fortunate thing for industrial countries, whose markets are now so well supplied that no one who has the money to buy food need fear starvation, but it has had melancholy results for the farmer himself.

Since it is the case that producers of foodstuffs for world markets arrange their business so as to provide full supplies in average seasons, there arises sooner or later a condition under which, from the producer's point of view, the market is overstocked and prices fall below the level which has hitherto met the cost of production. This condition may arise because of a succession of favourable seasons, or the advent of competitors new to the particular market, or to a fall in the purchasing power of consumers. In similar circumstances those engaged in other industries reduce costs of production, restrict output, or forgo profits, until an improvement is secured. The agriculturist can adopt the first and third expedients, he does try to lessen costs of production, he can and does forgo profits for a time, though his reserves are usually very limited. It is the second, and in the case of most industries the most effective, measure that defeats the food producer. So far from restricting output the agriculturist invariably attempts to maintain income by increasing production and a vicious circle of more produce less profit sets in until there is a collapse.

Even if we agree that the weakness of the producer's competitive position is largely the result of his own action, we must admit that it is action of a natural and reasonable kind. He cannot predict the seasons, much less the purchasing power of consumers, several years ahead, and though hard work may now be regarded by some as less virtuous than capacity for enjoying leisure, it is surely not a failing to be condemned.

Far from being regarded as a failing, the reaction of the farmer to the spur of necessity was throughout the greater part of the nineteenth century recognised as being of immense national value to the people of Britain. Porter, whom I have already quoted, in discussing, in 1836, the remarkable way in which farmers responded to the demands being made by a rapidly growing population for more food, makes the point that, by stimulating farmers to greater exertions, low prices had a double value to the nation.[2] It is well known, too, that throughout this period landlords and their agents frequently defended rent increase as being of national value, since land 'salted' with a high rent spurred farmers to make greater efforts. It was not until towards the end of the century that agriculturists themselves were fully convinced of the truth of the dictum 'high farming is no remedy for low prices.'

Reference has already been made to the great fall in value of the American farmers' output after 1920. An American economist [3] points out that although between 1920 and 1925 the area under crops had fallen and there had been a decrease in the number of farms and farm workers, there had been a more rapid increase in production in the United States than in any similar period since 1900, and this, it should be noted, in spite of the incentive to production that had been given by war prices between 1914 and 1919. Thus, so long as farmers in the States were solvent, low prices were more effective in stimulating production than high, for, as was the case in this country, while money was available it was used to improve cultivation.

The Canadian farmer's experience was similar to that of his neighbour in the States. Taking the price index of his field crops at 100 in 1926, the average for the years 1927, 1928 and 1929 was 96, but in the years 1931, 1932 and 1933 it fell to 43. In the first group of years the farmer put on an average 22·9 million acres under wheat, in the three later years 26·5 millions!

Mention has already been made of the reaction of Danish pig producers and New Zealand sheep farmers to falling prices; what has been happening at home?

From time to time many of you must have noted with pleasure, as I have, statements by Ministers on the rising agricultural output since 1932; substantial figures of 14, 16, even 18 per cent. increase in output have been announced, and with legitimate satisfaction, by political leaders. I myself, with equal satisfaction, have claimed the result as the harvest of much effort put into agricultural education and research by some of you who are present here to-day and by your colleagues in colleges and research institutes; but when shouts of 'sheep' and 'barley' arose in Lincolnshire in the autumn of 1938 and were repeated in many other counties, my pleasant reflections were disturbed and I began to ask myself: Have we been right in attributing this burst of

[2] In 1834 and 1835 wheat prices fell to the then low figures of 46/2 and 39/4 per quarter.

[3] O. E. Baker, U.S.A. Department of Agriculture, in *Graphic Summary of American Agriculture*, 1931.

activity, this large rise in our agricultural output, to Ministers and officials and scientific workers and county lecturers? Can it be the case that once again in our agricultural history we have been experiencing the results which have followed whenever the spur of necessity has been deeply driven into the unfortunate farmer?

Since the war there have been changes in the balance between producing and distributing industries and in our social conditions and habits which have further weakened the competitive position of the farmer in the home market. The increased spread in prices between the wholesale and retail markets by checking consumption have undoubtedly lessened the farmer's receipts. To the housewife food is not cheap, but its high price gives little aid to the farmer. If he received the same proportion of the retail price that reached him before the war there would be no agricultural problem for Governments; but as matters are the farmer's share of the increased price which the consumer pays consists mostly of the blame. This share is, indeed, generously apportioned to him whenever high food costs disturb the public mind. Within the past year or two his individual responsibility has, no doubt, been less heard of; it is the Marketing Boards that now make useful targets.

Take bread as an illustration of the spread of prices on the farmer's position. When, in 1906, I first went to London, the 4-lb. loaf cost $5\frac{1}{4}$*d.* and for his wheat the farmer collected 53 per cent. of the consumer's money. Last month the 4-lb. loaf cost $8\frac{1}{2}$*d.* and with the help of a subsidy the farmer collected 30 per cent. of the proceeds. I have seen the subsidy described as 'iniquitous' and I believe that this view of it is common; but if those who complain of the farmer were to get wheat for nothing the 4-lb. loaf would still cost as much as it did thirty-three years ago!

The spread in prices between the farm and the consumer has been a common experience in many countries since the war, especially in those countries where, as in the United States and Britain, the standard of living is high. An enquiry into farm and retail prices in the case of 58 articles of food has recently been made in the United States and this showed that, in the years 1933 to 1937, the farmer's share of the consumer's dollar varied from 33 to 45 cents. The lower the price level the smaller was the farmer's share, since intermediate costs are more or less rigid. The reduced purchasing power of the public in bad times hits the farmer severely; others in the food industries are better able to secure their share than he is and so the farmer gets what remains over when others have satisfied themselves.

In the post-war years there has been a notable increase in the number of persons employed in the distributing trades and in the number of shops. The number of insured persons employed in the distributing trades has risen from $3\frac{1}{2}$ millions in 1927 to $4\frac{1}{2}$ millions in 1938. There has been a very great demand on the part of the public for services, and because of unemployment in productive industries and better prospects in distributing industries, the latter have enlisted many more recruits than formerly. The finding of a livelihood in distributing industries by so many more people entails a corresponding levy on the goods sold. Theoretically the consumer should pay, but in fact the producer who consigns to any well-stocked market is certain to share the cost.

A second consequence of the increase in the demand for services is that it

is very difficult to prevent undue profits. They are restricted, no doubt, by competition and almost all enquiries into retail profits report that they are reasonable. Consumers are now very exacting in their requirements and unquestionably they are well served. Enterprising tradesmen may properly claim that they deserve to make money. It is undoubted, however, that many of them prosper in a way that few farmers do and the farmer would be much happier if the distributing services were less popular and more of his fellow-countrymen were engaged in the producing industries.

It is not that farmers are on bad terms with middlemen ; personal relations have always been friendly, and largely for this reason agricultural co-operation has been of slow growth ; but friendly relations do not prevent recognition of the fact that those who trade in foodstuffs do better than those who produce the goods. We live, no doubt, by exchange of goods and services, but while the pound, the pint and the yardstick help us to value goods, no ready standard is available to measure the value of the services now being demanded by consumers and we can only take note of the fact that in the exchanges of the food market the trend is for services to benefit at the expense of goods.

It is usual for British farmers to attribute their major difficulties to the fiscal policy followed by this country for nearly three generations ; this policy greatly benefited most of their fellow-countrymen and it had unfortunate results for many of them. But the fact that farmers in countries adopting quite different fiscal policies have suffered so severely in recent years shows that fiscal policy alone could not account for the difficulties of which primary producers complain. These I attribute to circumstances arising out of the nature of the producer's calling, circumstances which operate so generally and so frequently that they must be regarded as condemning him to occupy at most times a weak place in the food market. This weakness in the market place has resulted in the position to which Lord Stamp drew attention when, in 1931, he addressed the Farmers' Club on 'Agriculture and the Price Level.' 'My broad view,' he said, 'is that in the past hundred years agriculture generally has had to be satisfied with a perceptibly lower rate of return than the general rate. In this sense I would say that over a long period the world has been fed at less than cost price, assuming that in cost we include a standard and equated remuneration for service.'

The British farmer, long accustomed to listen to charges of, shall I say, a policy of 'encirclement' in food matters, will indeed welcome this statement by so distinguished an authority ; and now, when in discussions on subsidies and quotas and price-insurance, he is being denounced as a profit-minded aggressor on the National Exchequer, he may even be emboldened to seek the continued support of his fellow-countrymen by representing that these Exchequer grants, so far from being doles, are in fact deferred payments for services rendered throughout a long period during which he was impoverished and his country grew rich.

II.

With subsidies, price-insurance and other measures of the kind for assisting agriculture which at present occupy so much of the farmer's thoughts, the majority of scientific workers have no direct concern. The remedies for

agriculture's handicaps which they have to offer depend on research, and fortunately research is a remedy so widely approved that, when it does arouse criticism, the complaint usually is that too little use is made of it and that the financial resources provided are too meagre.

For criticism of the kind there is, no doubt, justification ; but in the past thirty years scientific research in agriculture has made great progress in this country and the prospects for further progress are now better than they ever have been. The subjects under investigation at our Research Institutes and University Departments of Agriculture are so numerous that the time at my disposal would not permit me to mention them all, much less to comment on them in any adequate way. My remarks on the scientific workers' programmes must necessarily be of a very restricted kind. Last year an extensive review of the investigations then in progress was published by the Agricultural Research Council and three months ago, in its annual *Farmers' Guide to Research*, the Royal Agricultural Society reviewed current work in agricultural science. Incidentally, may I say that the Society and its Journal and Education Committee are to be congratulated on the new and enlarged form which the hundredth volume of the Journal has taken. Part I of the Journal which was issued in June gives the motto ' Practice with Science ' a good send-off on its second century of endeavour.

As for meagre financial resources, no one can be more conscious of the needs and demands of the scientific worker than I am. During long years in Whitehall I have many times reflected that the doctrines of Malthus, confounded though they may be by twentieth century birth statistics, are peculiarly applicable to agricultural science ; the pressure of its annual recruits on the means of subsistence have given me many an anxious hour. Yet when I look back to the first years of the century when Hall, Russell, Percival and Theobald were breaking new ground at Wye, when Wood and Biffen were making the reputation of the Cambridge School of Agriculture, when Somerville had already shown how pasture improvement may be effected and measured, it is not the meagreness, but the growth of the resources now available to the agricultural worker that impress me. For I recall that, in the first report to be written by me in Whitehall Place, I had to point out that for the purposes of experimental work and research the State had granted no more than £380, whereas in the present year the Development Fund, which Mr. Lloyd George provided for us in 1909, is assisting the scientific worker in agriculture, and through him the British public, to the extent of some £500,000. And the Development Fund, although much the most important, is not the only source of funds available.

It is questionable if the general public realise how largely the programmes of the agricultural investigator are framed in the interests of the nation as a whole. Indeed, if these programmes were framed solely for the farmer's benefit, some of you, as you listened to my doleful account of the difficulties caused to the unhappy farmer by surfeited markets, may suppose that my remedy would be transference of the millstone of surplus from the shoulders of the producer to the neck of the scientific worker ! But although fully conscious of the large increase in world production recently brought about as a result of the activities of plant breeders, chemists, pathologists and others, I trust you will not think my logic faulty if I disclaim any such idea. A better

course is indicated. If we examine the conditions of the times in which the Royal Agricultural Society adopted the motto 'Practice with Science' we find in them circumstances recalling those which confront us to-day. For twenty years, from 1816 to 1836, agriculture had been passing through a period of very great distress, the sufferings of English farmers then were as acute as were those of farmers in the United States six years ago ; very many agriculturists were ruined and became labourers. But in spite of the hardships endured by individuals there was a bright side, substantial progress in the art of husbandry was being made, and as I have pointed out, there was a large increase in food production. With the first lifting of the clouds towards the end of the eighteen-thirties the optimism of farmers reasserted itself ; they took courage for the future and it was to science that those who were their leaders looked for help. It is interesting to note that, under conditions which show many points of similarity with 1839, the 1939 volume of the *Journal of the Ministry of Agriculture and Fisheries* announces on its first page, 'Science and Practice expresses the present purpose of the Journal.'

Can we equal the courage of our grandfathers and great-grandfathers? Their markets were assured, it may be said, but what of ours? Times have changed no doubt, markets have been difficult, but no more difficult for us than for the American farmer, and, recalling the fact that with those changes which have weakened in some respects the farmer's position there has been a great increase in the resources of science and in the skill of the investigator, let us look at America's reaction to depression.

In the United States, where the wheat surplus became literally a burning question, where swine met a Gadarene fate and where the misfortunes of the farmer were greater than anything we have recently experienced, what has happened to the programme of the scientific worker? Stringent administrative action was taken, as I have already said, to reduce surplus products and to restore healthy marketing conditions ; in all this work, as we should expect, the agricultural economist played his part. But there was no millstone for the neck of other scientific workers ; on the contrary, activity in the biological and physical sciences increased ; immediate steps were taken to survey the position reached in these sciences, and to prepare for the heavy task of reconstruction lying before the Administration.

The character of the measures adopted has been shown to us in the *Yearbooks of the Department of Agriculture* for 1936, 1937 and 1938. Until 1935 these yearbooks had consisted of short articles on many subjects, written by experts in popular language for the education of farmers. In 1933, in the depths of the financial crisis, a new decision was come to. Two great problems were faced : one of them the conservation of the country's natural resources, and especially of its soils, which had been cruelly treated ; the other, the improvement, by scientific breeding, of those plants and animals with which the farmer is concerned. By empirical methods much had been accomplished by breeders in the two preceding centuries, but new methods, introduced a generation ago, had wholly altered the outlook : thus the statesman who is now Secretary for Agriculture when he came into office set up a committee to survey the possibilities of what was termed 'Superior Germ Plasm.' The results of this survey have been given to the American public in the 1936 and 1937 *Yearbooks of Agriculture* and their purpose is made clear by the words of

Secretary Wallace, who wrote in an introduction : ' I trust that the day will come when humanity will take as great an interest in the creation of superior forms of life as it has taken in past years in the perfection of superior forms of machinery. In the long run superior life forms may prove to have a greater profit for mankind than machinery.' Those who have met Mr. Wallace and have listened to him speak at conferences will be likely to conclude that the possibility of creating ' superior forms of life ' has for him a very special interest.

Yet, as might be expected in an agricultural leader but two generations removed from the traditions of Scottish nineteenth-century farming, Mr. Wallace recognises that if agriculture is to benefit from superior forms of life there must be skilled treatment of the soil. And so the third of the yearbooks above referred to, that for 1938, which is entitled *Soils and Man*, has been written to raise the American farmer's future soil management to a higher level. Like the earlier yearbooks it is the result of a survey, in this case by the skilled officers of the American Soil Bureau in co-operation with the State Experiment Stations. The volume is intended to show Americans how very important a subject for them proper soil conservation is ; but in it there is much that is of interest to every country. Those of us who have long admired the energy and skill with which Americans have conducted their soil surveys must be gratified to learn how useful their knowledge is now proving.

The immediate lesson for those British soil workers whose studies extend to Empire problems is to enforce the need for more attention to soil conservation. Incidentally, may I congratulate our Secretary, Mr. Jacks, on his valiant effort to drive home this lesson in a recent book. *The Rape of the Earth* is at least a title that arrests attention, although perchance those who pull Mr. Jacks' book down from the library shelf, expecting a discussion on *Lebensraum* and enlightenment on the activities of dictators, may be surprised to find that man's inhumanity to soil, *not* man's inhumanity to man, is the subject.

In the United States the results of man's neglect have been melancholy indeed. In 1937 there were, we read, 415 million acres under crops, but of this total 161 million acres only could be described as being well managed and in a satisfactory state of cultivation. Some 253 million acres, because of their natural poverty, or because of erosion, were close to the margin of cultivation, while an area of land formerly under crops, and nearly five times as large as the arable area of Great Britain, had been ' essentially destroyed for tillage.' The comment of the Secretary for Agriculture on these figures is : ' This terribly destructive process is excusable in a young civilization. It is not excusable in the United States in 1938.'

From the foregoing examples of the action which has recently been taken it will be seen that, in the United States, no question of a millstone for the neck of the scientific worker has arisen. On the contrary all the knowledge and experience which have accumulated in that country since, in 1887, the Hatch Act gave agricultural research its first charter, have been drawn upon to provide enlightenment and new programmes of study for the development of its national resources.

And the policy which experience has led the United States to adopt is a policy which applies equally to ourselves. As is pointed out in a recent Rothamsted report, commenting on the difficult position of the British farmer,

' There are various possible remedies, social, economic and technical, but the line adopted at the experimental stations is to seek means whereby the efficiency of the farmer and of the worker can be increased, so that he may with the same expenditure of time and energy produce more food.'

Studies relating to the search for ' superior germ plasm ' are being vigorously pursued in Great Britain as in the United States. The narrow range of our climate limits the new forms which we ourselves could make use of; but in the Mother Country of an Empire whose climates vary from arctic to tropical the range is unlimited. The Dominions, the Colonies and India, have in recent years benefited greatly from the work of the plant breeder. The hunt for plants desirable in themselves, or as parents for new forms, is continuous. Australia, for example, has already introduced over 6,000 new plants from sixty-seven countries; again, as a result of a recent expedition to South America, our potato-breeding stations have acquired a number of new species of *Solanum*. My predecessor's plea for the extension of temporary leys can be realised more fully than now when the Plant Breeding Station, of which he is Director, provides, as it will provide, grasses and clovers as generally acceptable to farmers as were Sir Rowland Biffen's ' Little Joss ' and ' Yeoman ' wheats.

In Great Britain the climate and our farming methods have saved our soils from the fate of those of the United States, but again our students of soil have Empire conditions to consider. Nor can it be said that British soils are getting as much attention as they deserve. In this long settled country our very familiarity with soils has led to neglect. Samples taken from the field to the laboratory have, no doubt, long been examined by chemists; but, until recent years, soils as they occur in nature have been given little attention. Of most British soils it may even now be said that our knowledge of them has scarcely penetrated below the plough plan : but at least a beginning has been made and in limited areas careful studies are in progress. By learning from America and Russia, methods of soil surveying applicable to British conditions are being worked out; these methods are now sufficiently standardised to enable systematic surveys to be taken in hand and further progress in this direction is delayed only because of the small number of those who have been enabled to make the study of the soil *in situ* their main concern. A good deal has recently been said about the need for planning the uses of our limited area of land and arguments have been put forward with which I agree, but, for effective planning, I believe the first need is to reach a fuller understanding of the material for which we propose to plan.

To the great advances in knowledge of human nutrition which have been made since last the Association met in Dundee, our Agricultural Institutes have made important contributions. The Rowett Institute, indeed, from which is issued *Nutrition Abstracts and Reviews*, may be said to occupy a central place; while in stimulating the interest which the public now take in the better balance of the constituents of their foodstuffs no one has been more effective than the Institute's Director, Sir John Orr.

Agriculturists themselves have long been interested in discovering the correct balance that should exist in the constituents of the forage supplied to farm animals; thus the attention recently given to human diet, and to the effects produced by its deficiencies, have called for many studies in which

agriculturists and those scientific workers whose primary interests are in human nutrition have co-operated to the great advantage of both. But this recent co-operation does not justify statements suggesting that, until now, agriculture and human nutrition have been strangers to each other. It is surely very late in the day to announce that the time has come for a marriage between agriculture and nutrition. I myself supposed that this union had, in fact, existed ever since Adam delved in Eden ; thus it was with something of a shock that, in the preface to a recent notable book on British agriculture, I read that its purpose was to 'effect a true marriage of agriculture and nutrition.' It is surely unkind to suggest that until now the union of nutrition with agriculture has been illegitimate ! With a contributor to the *Journal of the Ministry of Agriculture and Fisheries* who writes of securing a 'happy marriage' I find no fault, for I do not contend that this old union has always been blissful. As I have pointed out above, agriculture has had a hard struggle and poverty does not make for harmony. There is indeed much that could be done to make the marriage a happier one.

Take, for example, the benefits that both agriculture and nutrition would derive from discoveries that would improve the health of farm livestock. By raising the standard of health in domestic animals we would meet some of the most insistent demands of nutrition experts. It is generally agreed that nothing would do more to reduce the number of C3's among us than an increase in the consumption of milk and eggs ; it is generally claimed, too, that to secure increased consumption prices must be less than they now are, and I believe it will be held by those who have studied costs of production that the possibility of lowering prices depends first and foremost on improving the health of the cow and the hen. So long as the wastage in dairy herds and poultry flocks remains at the present level, it is difficult to see how the cost of milk and eggs could be much reduced. To a less extent, perhaps, but still to a substantial degree the cost of other animal products is increased by the ravages of disease on our flocks and herds.

It was the extent of these losses to the stock owner, and their effect on the food supply of the public, that led the Agricultural Research Council, soon after it was established in 1931 and had surveyed the tasks confronting it, to decide that its main effort in the immediate future should aim at effecting an improvement in the health of farm animals.

With this object in view the Council formed technical committees which brought together for joint study those already engaged in the investigation of a number of diseases of special importance. It made grants for assisting research in numerous cases where additional funds were necessary. It employed trained surveyors to visit stock-raising districts, in which diseases, especially those of an obscure kind, were prevalent, and in this way collected much fresh information on the incidence of disease. Experience gained in work of the kind pointed to the need for a central Field Station at which it would be possible to carry out investigations on selected diseases on a large scale and under farm conditions. For this purpose the Council has acquired an estate of about 1,500 acres and this is being provided with laboratories, houses for the breeding of laboratory animals and isolated cattlesheds for accommodating animals under investigation.

The work of the Council on animals is paralleled by the assistance it pro-

vides for investigational work on farm crops. Committees of specialist workers have been set up, for example, on virus diseases, on plant diseases due to helminth attack and on insecticides and fungicides. One very active Committee, of whose work we shall hear at a later session, has been that on the Preservation of Grass and other Fodder Crops. Most of the special grants made by the Council for work on crops are in aid of pathological investigations. Until 1911 very little attention was given to crop diseases in this country, but when the Development Act provided funds, entomologists and mycologists were added to the staffs of most agricultural institutions and, as research workers or advisory officers, they have since given much needed help to agriculture and horticulture: thus the increase in fruit growing and other forms of horticulture that has taken place in recent years has been stimulated by the researches of plant pathologists and, as in the case of animal products, the nutritional demands of the public are being successfully met because of the invaluable aid which the scientific worker is able to give to the producer. Some of the best examples of 'Practice with Science' that the country can show to-day may be found in the orchards of Kent and other apple-growing counties.

So far I have referred to matters that engage the attention of the scientific worker, while agriculture follows what has been called 'its natural lines'; but unhappily for us our peaceful art must face the problems raised by war, and although opinions have been expressed and expressed freely on the subject in recent months, it cannot be said that there is any agreement on the rôle that agriculture either should, or could, be expected to fill in the event of war. Recent discussions, and my own experience in attempting to increase home produce during the Great War, lead me, therefore, now to refer to the scientific workers' programme in connection with home food production.

With respect to food supply there is, no doubt, agreement that during peace the country should store what it can; but when this has been done there are some who would make little effort to increase home-grown foodstuffs, they would trust to our ships. Others agree that plans for increased production must be in readiness, but would pass no order to 'speed the plough' until the bugle—or should I say the siren?—sounds; others again would advocate preparation for an uncertain future by aiming at a large increase of the area under tillage while the country is at peace. I myself belong to the last category. However great the effort that might be made after war broke out, I do not think that, as the country is being farmed at the present time, we could produce the foodstuffs that might well be essential in the waging of a long war. I believe, therefore, that apart from what we have recently been calling emergency measures we should now adopt an agricultural policy that would in future enable our soils to contribute more to our food requirements than they now can. I recognise of course that conditions have altered since 1918, but recent experience does not suggest that the lessons of 1914–18 can be neglected. It may be true that the aeroplane will force a quick decision, but wars in China and Spain do not support this view. It may be true that we have conquered the submarine menace; there is little proof of this and we know nothing of the effects of attacks from the air on shipping. On land the

fortified frontiers of European countries do not suggest that armies could force a more speedy decision than was forced from the trenches of France. Though it is true that, from the military aspect, great changes have taken place since the Armistice, it is also true that in the interval the requirements of the human stomach have undergone no change and that an adequate food supply is just as essential a matter for combatant nations as before.

If, in a future war, Britain is to rely, as in 1914–18 successfully, on its powers of endurance, then in my view an agricultural policy which would enable the country rapidly and largely to increase its output of home-grown food in case of need is the policy which Britain should adopt.

In the emergency of war it is a difficult matter to secure attention for needs which lie some time ahead. Energy is concentrated on meeting the requirements of the moment, or at most on those likely to arise within a few months. For the first two years of the Great War it was impossible to get agreement on a policy for increasing the food supply, and although some of us were well aware of our danger, it was not until the menace of the submarine was recognised early in 1917 that alarm for our supplies became general. That the menace was countered by the adoption of the convoy system in May 1917 is well known; but the subsequent difficulties in maintaining supplies which were experienced in 1918 are too little remembered. Those who may wish to learn more of these difficulties will find them illustrated in the correspondence between the Allied Maritime Transport Council and the Food Council which is published in Part VI of Sir Arthur Salter's volume on *Allied Shipping Control.*[4] This correspondence records the country's straits at a time when 90 per cent. of the world's tonnage was at the disposal of the Allies and when, apart from submarines then relatively undeveloped, the oceans were clear of enemy shipping. Under these conditions we were able, but only just able, to avoid the rationing of breadstuffs, a proceeding that, even with victory in sight, would have had dangerous consequences. The necessity was averted by cutting down the tonnage allocated to feeding stuffs for livestock. In the period January to August 1918 feeding stuffs had already been reduced to about one-third of normal requirements; but further cuts were called for in the autumn months and the needs of livestock were so meagrely provided for that a sharp reduction in meat supply must have followed later on had the war not ended in 1918.

In recent discussions on the subject of food supply in war, advocates of storage, of increased shipping for transport and of increased tillage for home production have all been heard, but too frequently as advocates of rival methods of providing supplies in war. It cannot be stated too strongly that these methods are in no sense rivals. All the aid that each can give would be wanted in a war of long duration. In the early stages of a war stores would be of especial value, throughout the period of hostilities all the tonnage which could be made available for the carriage of human and animal foodstuffs would certainly be wanted and in the later stages of a long war reliance might have to be placed largely on home supplies.

There was no provision by way of storage in 1914, but in 1915 and 1916 considerable stocks were accumulated. Even at the end of 1917 the country had fair stocks in hand. It was in August and September 1918 that we were

[4] Clarendon Press, Oxford, 1921.

forced to consider a policy that would have depleted these stocks heavily if the war had lasted into the late spring of 1919. It was then when, as I have just said, 90 per cent. of the world's tonnage was at our disposal and we controlled the seas, that the immense demand for shipping to transport America's armies and to convey foodstuffs for the Allies threatened us with a tightening of our belts that, but for the Armistice, would, I believe, have led our public to take a much deeper interest in post-war agriculture than in fact they have done.

Recalling our difficulties in the Great War, I cannot agree with those who would place their sole reliance on shipping for the 70 per cent. of our food which we now import. Even though we hope to command the sea, we cannot expect to do so as effectively as in 1918, nor are we likely to have so large a merchant fleet at disposal as we then had. According to estimates recently prepared by the Chamber of Shipping and the Liverpool Steamship Owners' Association the position is that, excluding tankers and ships of less than 500 tons, we had, in 1938, some 3,325 vessels, aggregating about 14 million tons gross, as compared with 5,000 vessels and 17 million tons in 1913. Even on the optimistic assumption that the submarine has been conquered, since we know nothing of the aeroplane's powers to hamper shipping, he must be a sanguine person who assumes that in a protracted war the call on the land would be less in future than it was in 1914–18.

It may be accepted, I think, that in any future emergency, while every effort would be made to maintain our normal diet, chief anxiety would be caused by the position of energy-supplying foods, in practice our breadstuffs. It was generally recognised in the Great War that the comparative absence of food difficulties then experienced was due to the circumstance that breadstuffs were not rationed.

In the pre-war years 1909–13 the country was producing about 35 per cent. of its energy requirements, in 1918 the Food Production campaign succeeded in raising the home supply to about 42 per cent. Entering the war with home supplies that would have maintained us for 125 days, we produced in 1918 the equivalent of 155 days' normal needs. Because of lack of labour, machinery and implements the difficulties we faced were extreme. With the number of tractors now available, grassland could be broken up rapidly ; but it is one thing to break up grassland and quite another thing to farm it properly, and it is the farming, rather than the breaking up, that calls for careful preparatory work.

But why break up grassland? That was the question asked in 1915 and 1916 ; it caused much controversy and would do so again.

The answer is that of human food, of the kind which we should chiefly want in war, other crops produce much more than grass. In the book *Food Production in War* already mentioned I have given many figures in support of this statement which I need not cite here : one general statement will suffice. In the years 1909–13 the soils of the United Kingdom maintained a population of about 15½ millions. I estimated that less than one-third of this total had been maintained by our 34 million acres of cultivated grassland (i.e. had been provided with the million Calories per person per annum necessary), and that over two-thirds had been maintained by our 13 million acres under crops other than grass. Per 100 acres of land 12 and 80 persons respectively had

been provided for. These figures, though they relate to the energy value of foods only and not to other things which are essential in our diet, give a fairly correct idea of the relative importance of grass and other crops in providing war rations. The chief reason for the very low production shown by grass is that a large percentage of our grassland is of poor quality and is grazed by store cattle and sheep. For the average pasture grazed by dairy cows my figure was 41 persons maintained per 100 acres ; well-managed grass carrying good cows might indeed provide the energy needs of 75 to 80 persons per 100 acres.

Because of the much greater productiveness of arable land than of grassland a ploughing campaign would be necessary in any future war, as in 1917–18, and a question of immediate interest is the addition to our home supply that might be made.

If a deduction is made for imported feeding stuffs used for farm animals it may be estimated that at the present time from 29 to 30 per cent. of the nation's energy requirement is provided by our soils. I have seen a German estimate, which places the figure as low as 25 per cent., but that, I believe, represents a case of ' wishful thinking.'

In 1918 after two years of effort we raised the then figure of 35 to 42 per cent. It is unlikely that we could now reach 42 per cent. after we had garnered a second war harvest, since in the past twenty years the area under crops, other than grass, in Great Britain has shrunk by some 3,900,000 acres. In the two years 1917 and 1918 we substituted about two million acres of other crops for grass. Since that time the supply of tractors has become large and labour difficulties in future may be less than in 1918 ; there is therefore the hope that, if again called upon, agriculture would do better than in 1918 ; but to reach the 1918 figure of 42 per cent. of the needs of the population (which has since increased) not only would a favourable season be necessary, but the plough would have to speed over twice the area broken up in 1917 and 1918. I estimate the percentage of our food supply that, farmed as the country is at present, we could expect to draw from our own soil at the second harvest after the outbreak of hostilities at about 35 per cent.

Our present systems of husbandry took form long before the aeroplane had to be reckoned with and they may be regarded as suitable for conditions that until recently existed, but I cannot agree that, as Europe now is, we should remain satisfied with methods of farming that, in war, would leave us dependent for some 65 per cent. of our food supply on imports. My personal view is that, for defence reasons, we must change to a more flexible method of farming than that which is now commonly followed, that we should adopt a system which under peace conditions would provide from 35 to 40 per cent. of our requirements and in an emergency would enable us rapidly to increase food production to a figure providing about half our annual needs. The change which, for defence reasons, I now advocate is that for which my predecessor argued at Cambridge on grounds of good farming, namely, a change over from permanent to temporary grass.

Sir George Stapledon advocated ley farming on an extensive scale. The adoption of this system would in his view improve the output of nearly all English cultivated grassland. For the purpose I suggest above it would not be necessary to replace more than from four to five million acres of permanent

grass by temporary leys. If, say, 4½ million acres were thus converted Great Britain would then have 16½ million acres under arable cultivation as it had fifty years ago. About 40 per cent. of the cultivated area would still remain under permanent grass, so that, in selecting the area for conversion into temporary leys, a wide choice would be available.

The substitution of temporary for permanent grass need not, in itself, call for substantial changes in the character of the land's output. The grassland would, as Sir George Stapledon stated, carry more stock, and if stock were paying better than crops the main change in output under peace conditions would be an increase in livestock products. From the point of view of war farming the advantages of temporary leys are obvious. The use of the plough and of other implements would be familiar to farmers cultivating temporary leys, but in many cases would be quite unfamiliar to those occupying only permanent grass. Tillage implements would be available on the farms on which they would be required in an emergency and the quality of the land itself for tillage purposes would be well known ; thus, in an emergency, arrangements for corn growing could quickly and easily be made.

The change which I advocate is a change that is called for mainly in England ; in Scotland the temporary ley is already the common practice. The value of the Scottish system for war farming was shown clearly in 1918. In that year, as the result of a very great effort, England increased her area under crops other than grass by some 20 per cent. as compared with 1914. In Scotland, where no special Food Production Department was at work and where opportunities for increasing the area of good arable land were relatively much less than in England, farmers with little outside assistance increased the area under crops other than grass by 15 per cent.

The special feature of the temporary ley as compared with permanent grass which gives it value to the nation for defence reasons is its flexibility ; but to the farmer himself the elasticity which this system offers has important advantages. Depending on the climate, and to a less extent on soil, temporary leys of any duration from two to seven, or more, years might be adopted. In the north-east of Scotland the shorter and in the south-west of England and Wales the longer periods would be suitable, but even on the same farm varying periods of ley could with advantage be adopted if the quality of the land made a rest in grass for different periods desirable.

In spite of the advantages both to the country and the farmer which can be claimed for ley farming, it must be recognised that in England there are circumstances which strongly tend to check the spread of the system. Permanent grass growing is the well-established custom of the country ; the change over from tillage to grass farming saved many from bankruptcy at the end of the nineteenth century and since that time grazing has, on the whole, been a safer business than agriculture. Again, short of capital as farmers are, it would take a good deal of courage to expend £3 to £7 per acre in forming a temporary ley, even if arithmetic proved that a return of 10 to 20 per cent. on the outlay may be expected over a period of years. The confidence of farmers in the future has been undermined as a result of their experiences since the war and much will depend on the extent to which confidence can be restored as a result of the Government's recent policy.

What is now called for is intensive research at a central station on the many

questions that would arise in connection with the conversion of permanent into temporary grassland, together with a close study of local conditions favourable and unfavourable for the extension of ley farming by economists and other scientific workers in different parts of the country. Sir George Stapledon himself is at some pains to explain that he is not an economist ; all the more need that we should put the economist on his tracks ! He has already persuaded a number of farmers to adopt his advice, and the results secured by men who have successfully turned from permanent to temporary grass farming would be of much value. Relatively the number of men concerned may be small, but I believe that they are sufficiently numerous to provide us with guidance of a kind that we cannot afford to neglect.

There are, indeed, features in the present situation which suggest that there is much scope for the economist and not only in connection with the interpretation of the experiences of grass growers. All readers of agricultural journals know that, in spite of agriculture's depressed state, there are within the industry many enterprising men who are doing well both for themselves and for their land. Their methods are certainly worth study and exposition and the audience waits. Thanks to such movements as the Young Farmers' Clubs and to the facilities for training provided by Farm Institutes, there are now in the country a large number of lads and young men keenly interested in agricultural progress and anxious to learn. Economic studies of the methods of successful men would be welcomed by these learners and by them would be translated into practice later on. The young farmers of my generation learned chiefly by example, and no doubt the young farmers of to-day continue to do so ; but to-day, much more than formerly, they are so trained as to welcome precept, if precept is based on economic studies of the kind I have in view. Thus in the process of converting some four or five million acres now in permanent grass into temporary pastures, which would be necessary to fit England to respond rapidly, as Scotland already can, to the call for increased food supplies, I lay much stress on the assistance which the economist can give.

The awakening of the soil, which would follow the breaking up of permanent grassland, would intensify the programmes of most other scientific workers and in some cases would call for substantially increased activity. This would be the case especially in agricultural engineering. Whether in tilling a larger area in normal times, or in rapidly extending the tillage area in war, no form of aid would be more welcome to the farmer than aid in selecting and employing machines and implements that would enable him to use manual labour to advantage.

In the ploughing campaign of 1917 and 1918 the presence of wireworm in the newly broken soil caused many crop failures. So far as possible the pest was countered by sowing crops not readily damaged, but this precaution was practicable on a limited scale only, and to-day wireworm damage remains one of our unsolved difficulties. Several scientific workers are giving detailed attention to the subject from the emergency point of view and it may be hoped that we may suffer less damage from this cause in future than we did twenty years ago, but there is still much work to be done before we can hope to regard the wireworm as other than a very formidable pest. In the case of existing arable land, which in war would be intensively cropped, eelworms and the

foot-rots of cereals would also be likely to do much damage. Like wireworms they require and are now receiving special study.

Many other matters would call for the attention of the scientific worker in war; some of them could be predicted because of 1914–18 experience, others could not, for one thing learned in 1914–18 was that war throws up new and unexpected problems. On the precise nature of these problems we need not now speculate, rather let us note that the scientific worker is confronted with one very definite objective. This objective, which must be approached from different angles, may, in a sentence, be stated to be the preparation of British Agriculture to expand its normal output of food rapidly if called upon to do so. The immediate aim should be the provision of a six months' supply of food for the nation in an emergency.

Many of those who have considered the subject of food supply in war would not agree with the views I express; they would point to agricultural experience in recent years and argue that the production of half the nation's food from the soils of the country would be impossible. But while I admit that experience since 1919 has not been encouraging, my view is that our present tendency is to underestimate the capacity of our agriculture, and I claim that our outlook should not be restricted by the experience of the past twenty years.

There is little amiss with the soils, or the climate, of Britain, our tillage land responded well to the calls made on it a century ago and would respond again; our farmers taught those of most other countries and if their pupils are now, in some cases, ahead of them, there is no lack of farming talent. Research and education in agriculture have been with us for a generation; growth may have been slow at first, but advances are now being made at a rate that is encouraging and we may confidently expect much more aid from science in future than it has given us since 1919. Thus from the technical point of view I see no insuperable difficulties in the programme I have outlined.

From the point of view of farmers themselves, however, the case is otherwise. If they and their employees are to earn as meagre a share of the national income in future as they have done in the past twenty years a further decline in the arable area is only too likely, for the reason that, under recent conditions, masters and men have lost confidence in their future prospects.

There is an atmosphere of 'defeatism' about and not only among agriculturists themselves. There is too ready an acceptance of the doctrine that economic changes have condemned the land of England to slumber under grass and that economic reasons forbid its awakening by the plough. As matters are it would certainly cost the nation money to bring several millions of acres back into arable cultivation and to substitute temporary for permanent pastures; but if the change were made, not only would we add largely to the agricultural output, but there is, at least, a prospect that farmers would find themselves better off than they now are. In my judgment the ease with which tolerably good grass can be grown in many parts of England has led far too many farmers to bury their talents under the greensod and too many farmers, as well as their counsellors, believe that it is prudent to leave these talents buried; but looking to the future I am satisfied that good and faithful service to the country calls for a change and I hope for a change that would be rewarded. To science I look for assistance in bringing this change about and, for the

farmer's reward, to the belief that the world's non-agricultural inhabitants cannot expect a continuation of the conditions which, during the past century, have enabled them to buy their food at under cost price. But these conditions may not quickly alter, while changes in farming are needed now, and as I have admitted that the nation must pay before large changes in our methods of cultivation can be expected, I will be asked why should the nation pay ?

We fervently hope that war may be averted and most of us believe that in the immediate future the better our preparation the less is the risk of war. But can we hope that the shadow of war will soon disappear from Europe, where German children are being taught to hail a new saviour, where German youth are persuaded that might only brings right and that brutality is an essential constituent in man's make-up ? No one who knows anything of that nation can hope that the effects of the training its youth are now getting will quickly pass, or that we can soon look forward to the goodwill among men which brings peace on earth. Whatever the next year or two may hold in store, Britain, hateful as the prospect may be, cannot afford to neglect preparations for defence. And in these preparations agriculture must have a place. How large this place should be is a matter of opinion. My personal view, based on experience gained in 1914–18, is that it should have a large place ; but be its place large or small it is for services rendered in connection with defence that farmers can legitimately ask the nation to pay, as it is paying, and paying heavily, for the services of others similarly engaged.

Thus looking to the future I conclude that the century-old motto which heads my paper is still applicable ; the nation which relied on the British farmer for its food supply in 1839 cannot do without his aid in 1939 ; while he himself, if he is to do his part as his forefathers did, must take as his watchword ' Practice with Science.'

SECTION M.—AGRICULTURE

COMMUNICATIONS

Mr. A. Howie.—The breeding and feeding of beef cattle.

The breeding and feeding of cattle for beef is a sign of a high standard of living, and to supply the epicureans at the heart of the British Empire the farmers in the north-east of Scotland have earned a name which is second to none in this branch of agriculture.

The essential preliminary conditions for breeding and feeding of beef cattle are :

1. A favourable climate.
2. Suitable soil.
3. A sheltered situation.
4. Good buildings.
5. An experienced and intelligent cattleman.

Given these, the main factors in the actual process of breeding are :

1. The purchase of good milking heifers, and especially the purchase of a good bull. Certain breeds are favoured.
2. Calving at the proper time.
3. Keeping calf flesh on the animals after weaning.
4. Concentrates after weaning.

Methods are described in detail, and the summer and winter feeding of purchased stores for commercial purposes is discussed.

The economic side of the question is complicated, but the author has kept records of feeding and other costs and sales for a long period of years.

The snag in cattle-breeding is the incidence of disease, and its prevention is discussed and some scheme of sickness insurance is suggested.

The author's experience is that cattle-breeding and especially cattle-feeding is the most important branch of British agriculture. It is actually the key industry, and if it is put on a sound basis it reacts favourably on all other farm activities and makes Government encouragement for most other farm products unnecessary.

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Principal W. G. R. Paterson.—Sprouted fodder in cattle feeding.

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Mr. W. Godden.—Pre-digestion of coarse fodders.

During the present century and mainly since 1914, various methods have been proposed for the treatment of straws, and in some cases of wood, with a view to enhancing the nutritive value of the material. Various processes have been suggested, viz. :

1. Steaming without chemicals in open vessels or under pressure.
2. Treatment with acid.
3. Treatment with alkali in the cold : (*a*) with caustic soda, (*b*) with caustic lime.
4. Boiling with alkali in open vessels.
5. Cooking with alkali under pressure.

In all cases the main object has been to increase the digestibility of the fodder and to provide a material which would be a valuable source of readily digestible carbohydrate.

Most of the digestibility trials and feeding experiments have been carried out with ruminants with favourable results, but there are indications that such pre-digested materials could be used equally well by pigs.

The literature is reviewed and recent trials carried out in this country are reported.

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Discussion on Agricultural education.

Mr. G. MacGregor.—Fife experiments in agricultural education.

Mr. A. R. Wannop.—Young farmers' clubs.

Prof. N. M. Comber.—Advisory work in relation to agricultural education and research.

Farming is an age-long art into which the essential need for technical knowledge has come but recently. The coming of this need brought into being a body of agricultural educationists—experienced in farm practice and trained in schools of science—who were devoted to systematic instruction of people entering the farming industry, and to advising on specific problems. Later the more specialised work of research institutes developed, and a specialist advisory service was formed.

There are now three groups of interrelated factors involved in the technology of farming.

1. The technical education of the farmer.
2. The securing of new knowledge by research.
3. The implementing of new knowledge in farm practice.

At the present stage in the development of agricultural education there is a serious lack of balance and co-ordination between these factors. The developments in the acquisition of new knowledge have been much greater than the developments in the technical education of people entering upon farming, and the implementing of new knowledge is, therefore, impeded.

A statesmanlike consideration of the immediate future of agricultural education must see the urgent need for securing balance among these factors and for co-ordination, in organic unity, of those concerned with systematic technical education and those concerned with advisory work.

Public opinion in favour of technical agricultural education is still in the early stages of being formed, and one important factor in forming it will be the influence of specific advisory work in inculcating an appreciation of the need for systematic education.

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Discussion on Grass conservation.

Mr. Martin Jones.—The place of grassland in modern food production.

Grazing used to be the most economical method for production of meat and milk for a number of reasons, but required the people to live in winter on salted meat and butter with very little milk.

To get fresh food in winter man had to grow arable crops, but these did not come up to modern requirements with respect to vitamins, minerals and essential proteins.

Recent developments in grassland use have made it possible and economic for grass and grass products to be used in the production of winter milk, winter lamb and winter eggs, as well as helping in the more economical growing of cereals.

The rôle of strains in herbage plants and their management for persistency, together with maximum production at critical times, is discussed.

Dr. S. J. Watson.—Scientific aspects of grass conservation.

After considering the productivity of good grassland, the need for efficient conservation is discussed. The most usual method, that of haymaking, is associated with fairly high losses which extend to the carotene content of the original crop.

The artificial drying of grass is considered next, and it is observed that the nutrient losses are very low indeed. This is also true of the carotene. The high biological value of the protein in dried grass is noted, and seasonal variations are briefly discussed.

The third process is ensilage, which depends on the observance of certain very simple principles. The losses in the modern processes, where molasses or acids are added, are low, though not so low as in artificial drying. The use of cheap portable silos has brought the improved silage processes into favour. Silage is a good source of carotene, and mineral matter can easily be added during making.

The value of dried grass or silage is discussed in relation to making the farm self-supporting or increasing its stock-carrying capacity, and it is pointed out that the conservation processes are complementary and not antagonistic.

Typical rations are given, using the different conservation products. The proper utilisation of the different grass products is a very important aspect of conservation and must be taken into account.

Mr. E. J. Roberts.—The economics of grass conservation.

Young grass, a valuable feeding stuff, may contain a proportion of crude protein varying from that found in good hay, i.e. about 9 per cent., to about 20 per cent. or more ; it can supply most of the wants of farm animals. If such young grass

could be conserved for use in winter efficiently and economically, it would enable grassland to make a more balanced contribution towards maintaining our livestock.

Two methods of conservation are possible, ensilage and artificial drying. The economics of these methods are discussed. Recent advances in the making of grass silage, by the addition of molasses, acid, etc., and by the provision of portable silos, have opened up possibilities for this method of conservation. One of the disadvantages of ensilage is the handling and hauling of about 4 tons of water with every ton of dry matter. Artificial drying gives a satisfactory product, with less loss of nutrients than ensilage. The costs of production vary rather widely from farm to farm. Some can produce dried grass at a price that compares favourably with that of ordinary purchased concentrates ; others produce it at a price that is only economical if the product can be sold as a source of carotene, etc., for incorporating in feeding stuffs.

Experiments have been arranged to compare ensiling and artificial drying on the same farms. In this way, it is hoped to conserve the grass from equal areas of land by the two methods, and to obtain the results, which include costs, in terms of milk, live weight increase, etc.

Prof. W. Kerr.—Some engineering aspects of grass conservation.

* * *

Discussion on Seed potato growing.

Mr. T. A. Wedderspoon.—Seed potato growing.

Dr. G. Cockerham.—Virus diseases and seed potatoes.

There has been a steady improvement in the health of Scottish stocks of seed potatoes since the introduction in 1932, by the Department of Agriculture for Scotland, of a scheme whereby virus diseases are taken into consideration in grading potato crops for seed purposes. Nevertheless, virus diseases, particularly in their milder forms, continue to provide problems of great magnitude to the Scottish seed potato industry. Analysis of data furnished by the annual inspection of 1937 has indicated that some of these problems are related to the area in which crops are grown, and that others are intimately associated with the varieties in commercial demand. A major problem affecting the whole country, however, arises out of the ubiquity of virus X. In varieties tolerant to this virus, symptoms may be evoked ranging from those of negligible mottle to severe mosaic. As the virus is independent of insect vectors for dissemination, the environmental advantages for potato seed production offered by the greater part of Scotland are defeated and a large acreage of potatoes has to be graded (H) in place of a possible (A) were the effect of virus X eliminated. The replacement of tolerant varieties by intolerant or ' field immune ' varieties offers a probable solution to this problem.

Dr. T. McIntosh.—The importance of the variety in potato production. *(11.20)*

The popularity of the potato depends largely on the great diversity of characters found in the various varieties : the acreage devoted to the crop would be very much less were *S. tuberosum* homozygous, like some other solanaceous species. The special characters of varieties, however, can be appreciated only when stocks are free from impurities and variations. The maintenance of purity is discussed, and the very beneficial effect of the official inspection scheme is shown by figures relating to Scottish stocks. Variations and their effects on yields are examined. Many variations found in potatoes are periclinal chimæras, and the normal forms may be recovered from them by special technique. Other variations are considered and some of the author's own variations, produced experimentally, are described, an explanation of their origin being suggested. Special emphasis is laid on the peculiarities of individual varieties from the cultural standpoint. In dealing with

varieties in relation to virus diseases, particularly those caused by viruses A and X, a scheme of planting for use when several sorts must be grown in the same field is proposed. In conclusion, the author deals with the raising of new varieties and stresses the necessity for a wider breeding policy on scientific lines, including the production of types immune or highly resistant to blight and virus diseases. In this connection, the value of species other than *S. tuberosum* for introducing these characters into new varieties, and the importance of the provision of tests for seedlings in their early stages are emphasised.

LOCAL SCIENTIFIC SOCIETIES AND THE COMMUNITY

ADDRESS TO THE CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES

By Prof. HERBERT L. HAWKINS, D.Sc., F.R.S., F.G.S.

PRESIDENT OF THE CONFERENCE.

Through the whole range of Nature, classification shows an underlying simplicity of principle expressed through various materials and in diverse grades. Gravitation controls galaxies and sand-grains, and evolution is the common destiny of genera and of individuals. Both of these fundamental principles tend inevitably to pile up aggregates of ever-increasing size and complexity. But such aggregates are collections of units, and, while appearing to acquire new properties, remain subject to the laws that govern units, and dependent on the reaction of their components to those laws.

Human nature, despite the bombastic claims often urged by its exponents, illustrates the operation of the principle of evolution with painful fidelity, especially in its social reactions. From the lone hunter through the clan to the totalitarian state the process of aggregation goes on, with increasing complexity and decreasing flexibility, until Nemesis clears the stage for the next performance. Within the frame of natural or imperial unification are innumerable smaller aggregates, each so similar in type to the whole that one is reminded of a crystalline fabric, where each molecule has a shape consistent with that of the complete crystal.

A scientific society is but one example of this tendency towards congregation of kindred types. Whatever may be its peculiarities, its success or failure, each society has originated in much the same way as all the others. In most cases, its history can be traced back to the enthusiasm of an individual, who has attracted and stimulated a small coterie of friends or disciples. Organisation has followed ; and, whether it was invented or adapted from previous models, it has produced a miniature copy of a democratic state, complete with cabinet and treasury.

The aims of these societies vary somewhat, some being devoted to research, others to instruction. The former type of society is in constant danger of decline, for it needs continuous stimulation by new enthusiasts in successive generations ; the latter is fortunate if it avoids the comatose senility of a social club.

Sociability is, however, the key to the success, and almost a *raison d'être*, of a local

society. Unless this is an association of friends, it belies its name and loses its efficiency. It is not in the academic eminence of its members, but in the spirit of co-operation and enjoyment, that the value of the society lies. For this reason a society that organises field-excursions as an essential part of its programme is a far more lively institution than one where the members meet only in the enforced silence of a lecture-hall. The element of friendly intercourse may, naturally, degenerate into a mere picnic ; but even that is preferable to the priggish snobbery of a lion-hunt.

A society attracts to membership others besides those whose natural enthusiasm marks them as leaders in its enterprise. Although the danger of over-emphasis of the social side may be thus increased, such recruits are to be welcomed. Some may become interested and inspired, but all will contribute something, be it only a subscription, to help the society's work. No government can hope to carry out its schemes without the backing of a body of reasonably willing tax-payers.

The present is not altogether a propitious period for the advance of local societies. Although the proportion of the population capable of appreciating the aims of the societies is perhaps greater than formerly, the increase in the opportunities for recreation tends to reduce the personnel for any particular form of activity. Its local character is an essential aspect of a local society, and the metropolisation of the provinces by transport and wireless-telephony has obliterated much of the individuality of districts. Most societies deplore the lack of youthful recruits, and look forward with anxiety to decreasing membership.

In the great majority of cases, the members of local scientific societies are 'amateurs' in the generally accepted sense of that term. Their scientific work is their hobby ; and in the present pressure of business life few have time or energy to spare for a pastime that demands intellectual effort. The young prefer forms of recreation that involve strenuous and often exhausting physical exercise, while the middle-aged tend towards somnolent recreation. Not until retirement ensures leisure for following their own devices can most business-men undertake the responsibilities, or even enjoy the privileges, of active membership. To such, a scientific society may offer hope of survival, and of congenial activity, beyond the critical phase at which it used to be customary to receive an inscribed clock to mark the last few hours of life. Local societies can confer benefit on these and on themselves by attracting them to membership. Individually they may have poor actuarial prospects of permanence ; but as a class they are available in ever-increasing numbers.

Probably the most fatal disease that can overtake a local society is that which gives it a reputation for erudition. If there is any truth in the fear of a prospective member that he or she would feel ignorant in a company of savants, membership should be avoided at all costs, for the society is not worth joining. Interest, not intellect, should be the gauge of suitability ; humble inquiry is more appropriate even to the specialist than declamation of a learning that is only ignorance in disguise. Mutual sympathy and encouragement must be the spirit of the society ; all are there to learn, and no teacher needs to be reminded that he learns at least as much from contact with keen students as they are likely to learn from him.

So much of the useful work, and maintenance of interest, in scientific matters depends on casual every-day observation, that aspects of Nature ready to hand for the majority of members are likely to receive and give most satisfaction. A society in a coastal town can obviously foster the study of marine conditions that would be outside the practical scope of one in a midland industrial city. While retaining an intelligent curiosity in respect of any and every thing in the universe, a healthy local scientific society will normally tend to focus its main efforts on locally appropriate topics. In this matter, the term 'locally' may apply to some especially vigorous member, whose enthusiasm for his particular bent infects many of his colleagues,

and, for his generation at least, overshadows the milder activities of those who have escaped contagion. Such waves of fashion are perhaps inevitable ; but they are not altogether desirable. Hero-worship falls very flat when the hero proves mortal.

Most local societies are devoted to 'Natural History' ; very few take much cognisance of the physical sciences. When specialisation is made, the two subjects of Geology and Archæology are those usually selected. Evidently the main function of a local society is its provision of relaxation for people who have no technical training in science. Outdoor interests offer far healthier spare-time hobbies than laboratory studies where elaborate calculations or stiff reading give no respite to jaded minds. An attractive feature of the Natural Sciences is the scope they afford for the making of collections. From early childhood the jackdaw-complex is deeply ingrained in most of us ; and although specimen-collecting may become a vice, it shares that risk with all other virtues. So long as mere miserly acquisitiveness is avoided, the arrangement and study of collected material can revive memories of past thrills and prolong the joys of field-work. This matter of collections is so important that it may be discussed somewhat fully.

An important duty of every scientific society should be the control, by precept and example, of the mania for collecting. Especially in the case of living things, due regard for the preservation of rarities must check wholesale destruction. It is pleasing to be able to record a great improvement in this respect achieved in recent years, largely through the influence of local societies. The days when a rare plant or animal was ruthlessly slaughtered in the name of Science are past—even game-keepers (who are rarely members of our societies) are less promiscuous in their attacks on any creatures worth preserving. We are even beginning, with the inspiration of the Council for the Preservation of Rural England and the National Trust, to frown upon, rather than to condone, vandalism done in the sacred name of Mammon.

But there yet remains ample scope for the training of collectors ; and almost every society is likely to include some members who can guide and counsel the uninitiated. Collection involves dissociation of the specimen from its natural environment ; in the majority of cases that environment is one of the most informative features of the specimen. It cannot be brought away in substance, but it should always be recorded in writing with all possible detail. Paradoxical though it sounds, it is nevertheless true that a collection of specimens without adequate labels is less useful than a collection of labels without specimens. Every particular of the circumstances attending the collection of the specimen should be written down at the actual time and place—memories get blurred at the end of a day. Even details that seem irrelevant should be noted ; wider experience may show that just such points had the greatest significance.

If all the material that clutters up our museums had been collected in accordance with that simple principle, its value for scientific research would have been enhanced a thousandfold ; the charnel-house would have been a biographical library. One battered fragment with a history is worth a score of 'plums' without a label ; for there is more satisfaction in scientific circles over one poor specimen with particulars attached than over ninety-and-nine perfect examples that have no such accompaniment.

In the matter of collecting, the local society has no need to encourage an inborn instinct, but rather should guide and restrain. A collection made for a definite intellectual purpose is unlikely to lead to decimation of its materials. But the collecting of specimens is really a pandering to low instincts ; a far more important and fruitful activity is the collecting of facts. Except when they are needed to substantiate a record, or are required for intensive research, objects observed are often better left where they are. This policy of restraint does not apply to inanimate objects, which may be preserved by being taken under cover ; but in the case of

living things it is unusual, and surely unnecessary, to prove that one has met a friend by bringing his corpse home as a witness.

In the matter of research, the greatest contribution (other than encouragement) that can be made by scientific societies comes from their ability to keep, check and publish records of transient phenomena. Every recurrent seasonal event in Nature invites, and often receives, accurate observation. Whether it be the first cuckoo or the last swallow, the flowering of the primrose or the ripening of the holly, it is apt for, and deserves, a permanent record. In such work the society, as distinct from the individual, has a special value ; for records without independent confirmation are of uncertain use. Moreover, a record, however well authenticated, of a single phenomenon gains immeasurably in importance when taken in conjunction with other records of contemporary events. The dates of appearance and disappearance of living creatures are shorn of half their significance without statistics of the weather for the season. The arrival of a migratory bird in any district may prove to be controlled by the appearance of a particular insect, and this again may depend on the growth of the insect's food-plant, which may have been determined by the weather-conditions of the current or past season. The keeping of statistics thus becomes a matter of team-work ; ideally every Natural History society should include observers who keep accurate and unbroken records of data on every conceivable topic capable of such treatment.

Accurate prophecy is always based on knowledge of past history correlated with a perception of the laws of cause and effect. Statistical records such as those indicated would provide the raw material of prophecy ; if such truly natural history of but a few decades were available, it would aid in forecasting just those tantalising mysteries that every farmer, and so every consumer, wants to know. Just as a straw shows the way of the wind, so some obscure animal or plant might, if its significance were realised, provide an answer to problems of immense practical importance. The most sophisticated social order depends ultimately on Nature, and common sense demands that the foundation of the social fabric should be studied. There is endless useful research awaiting the efforts of local observers in this indirect aspect of Man's place in Nature.

As regards geological and archæological studies, there can surely have been no period in the past more favourable than that in which we find ourselves to-day. For one reason or another, excavation is a dominant feature of our present activities ; and, however shallow it may be, every hole is likely to reveal something of interest. Modern methods of excavation are so speedy and mechanised that much of their revelations can be observed only by perpetual watching. Here the local society can find scope for important and urgent work. Every society should acquire a large-scale map of its area, and plot on it every site where a glimpse, however fleeting, of the subsoil has been possible. Pin-pricks on the map, with numbers written against them, to correspond with card-index entries giving all the particulars, would soon make the map a priceless record. Only accuracy and persistence are wanted to achieve results that could not fail to increase the knowledge that all local societies are nominally out to acquire. Probably most societies include one or more members with the business experience needed to keep the records in order, and every member could contribute to them directly or indirectly. The volume of local knowledge already stored in the minds of residents is impressive ; if that knowledge were to be methodically recorded, it would outlive its original possessors and so contribute to something more permanently satisfying than reminiscent causeries.

The suggestions for activity outlined above may seem to be more concerned with the relation of scientific societies to Science than with their reaction on the community at large. Such a view is not only narrow, but out of date. In the present critical times, statistics of the resources and character of the country are being feverishly compiled. There could surely be no better compilers than those residents

in any district who have trained themselves to observe facts and to tabulate them methodically. Such problems as the yield of springs and wells, the availability of road-metal, sand and gravel, the quality of the soil, the incidence of blight and the usefulness or otherwise of our fellow-inhabitants, are all of a nature that demand accurate observation on the spot. Many of them may involve elaborate technical study as well; but the first stage of all of them is within the capacity of any reliable observer. All who love their country (in both senses of the word) can find here congenial and valuable work that is needed urgently.

The proportion of the population likely to join, and participate in, a scientific society is inevitably small; but that is no reason why it should not serve as a leaven. The study of natural history produces a philosophic outlook that should supply a much-needed corrective to the world, and can mitigate the worst attacks of the flesh and the devil. The mere existence of a company of people declaring their interest in matters bigger than the squabbles of the political nursery, preferring to contemplate wider problems and vistas than those of the daily headline, should be enough to ensure a nucleus of stability in the quicksands of opportunism. Science is a search after the truth; its devotees should be sure of their gospel, and declare it in a world of falsehoods: *Magna est veritas, et prevalebit.*

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES

COMMUNICATIONS

Dr. Murray Macgregor.—Preservation of geological sections.

The value of preserving geological sections of outstanding or critical significance has long been recognised. They may illustrate unique episodes in geological history, they may represent landmarks in the progress of geological speculation, they may require reinterpretation in the light of modern research. For these and other reasons—historical, educational, and scientific—the question of their preservation is undoubtedly an important and challenging one for geologists throughout the country. Moreover it is essential, in the opinion of the present writer, to include within its scope the preservation in a carefully documented and permanent form of geological records of all kinds. Machinery for dealing with borings for minerals already exists, but there remains a wide field not covered by any co-ordinated activity. Important geological data may often be obtained, for example, from temporary exposures in tunnelling and quarrying operations, sewerage schemes, housing and factory extensions, and the like. Examples of such records and of their value for purposes of research are given and the suggestion advanced that local geological and natural history societies should be invited to collaborate in this work, under the guidance of a central co-ordinating authority to which annual reports might be submitted.

* * *

Prof. W. T. Gordon.—The preparation of scientific papers for communication and publication.

In a recent letter to the Secretaries of the Royal Society, Dr. C. G. Darwin voiced the dissatisfaction that prevails among scientists regarding the presentation of the results of research, and has suggested means of improvement. Devoting attention

to the type of research that is one term of a series, he worked out a rough time table, based on a twenty minute address, that an author should have in mind.

The suggestions advanced here are directed more towards the presentation of descriptive or of biological papers, though not exclusively so, and are specially concerned with communication of the results of research to a general audience.

The remarks are addressed to the Delegates of Corresponding Societies as the most appropriate body in the British Association, since the societies we represent usually possess relatively simple apparatus for demonstration purposes, and more detailed attention is therefore necessary if interest in scientific research is to be fostered.

Under ' Presentation of Results,' therefore, the construction of diagrams and lantern plates is discussed, and examples selected to indicate what should, and what should not, be attempted with an audience of 100 to 150 and a time allowance of about thirty minutes.

In discussing the preparation of papers for publication, chief emphasis is laid on the illustrations, because most societies have rules that an author must observe concerning the letter-press. Assembling of illustrations into plates is considered with a view to secure not inartistic results.

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Discussion on River pollution.

Prof. F. G. Baily.—New legislation required for the prevention of river pollution.

The story of river pollution begins with a Commission of Enquiry in 1868, and the Act of Parliament, 1876, still the main Act. The discharge of polluting material into a river is declared illegal, but many exceptions are allowed, resulting in another Commission in 1898, a Standing Committee in 1921 and an Advisory Committee (for Scotland only) in 1928 who are still reporting. Various Acts since 1876 prohibit certain forms of pollution or protect certain rivers, but nothing effective has been achieved though the Commissions have strongly condemned the state of the rivers.

A report of the Scottish Committee in 1936 recommended changes in the law. The Act of 1876 gives to local authorities the guardianship of rivers within their respective areas, but as domestic sewage is an important source of pollution for which they themselves are responsible, they can scarcely proceed against others. The Committee advocates a River Board for each watershed or group of small ones, similar to the Thames Conservancy Board, with the duty of preventing pollution; and suggests standards of purity for effluents and for the rivers, with systematic inspection and testing, the ultimate control being with the Secretary of State for Scotland.

Sir Robert Robertson, K.B.E., F.R.S.—The work of the Water Pollution Research Board.

1. *Work of the Board* and its terms of reference.
2. *Publications of the Board.*—Annual reports and technical papers.
3. *Trade effluents :*
   (*a*) Sugar-beet effluents. Re-use of water and purification of effluents.
   (*b*) Milk effluents. Purification according to two processes.
4. *River pollution.*—Description of an intensive study of a river—the Tees—from hydrographical, chemical and biological aspects.
5. *Water supply.*—Base-exchanging processes. Removal of lead.
6. *Sewage purification.*—Basic information as to the mechanism of existing methods, e.g. the activated sludge process. Large-scale experiments.

Dr. R. W. Butcher.—The effects of river pollution on the freshwater flora.

The effects of polluting effluents on water plants are very varied and may be divided roughly into three groups :

(1) Organic effluents not directly toxic ;
(2) Directly poisonous mineral and organic effluents ;
(3) Non-poisonous mineral effluents.

Organic effluents such as those from breweries, beet-sugar factories, milk factories, slaughter-houses, and principally sewage, when strong, cause a growth of sewage fungus only, and the deposit of a black foul silt which often smothers the flowering plants. They also deoxygenate the water. Weaker effluents increase the alga growth and, through them, the general productivity of a stream.

The varied poisonous trade-effluents produce different reactions on the plants and animals. Those containing chlorine, for example, appear to kill both microscopic plants and fauna, though not the flowering plants. A copper works effluent was found to destroy all the animals but not the plants. Gasworks effluents are usually toxic to fish but do not change the flora. Arsenic apparently kills flowering plants easily but is not toxic to animals and algæ. Rivers polluted by such poisonous effluents may appear healthy from the usual chemical analyses or from the general look of the river.

Non-poisonous mineral effluents include coal washing, gravel washing, china clay and similar substances. They completely cut off the light from the river bed so that plants starve and die and, as a consequence of this, and also because of the continual deposit of fine silt on the bottom, the fauna is very sparse and fish must starve or migrate. Here again the oxygen content and lack of organic matter might indicate satisfactory conditions.

Mr. W. Malloch.—River pollution and its effects upon freshwater fisheries.

Our rivers, streams and watercourses form part of our great national resources. For centuries their use for primary purposes was recognised and respected. During the industrial revolution they became facile channels for the disposal of effluents and waste of all kinds. Noted salmon and trout rivers like the Clyde, Cart and Leven became open sewers. New forms of pollution arise whose effect is only ascertainable after the plant has been installed. The process of denuding our rivers of their valuable fauna continues unabated. The author has come across many examples of pollution. The most obvious are those which produce immediate mortality amongst fish, such as effluents from bleach works, gasworks, paper mills, distilleries, cheese factories, or from waste sheep dip, washing of fertiliser bags and potato-spraying implements. Others again, tarred road and mine washings, waste garage oil, diluted domestic sewage, etc., destroy insect life and the streams become uninhabitable for fish. The process is delayed but just as disastrous. There are other forms of pollution, less well known, where barriers of deoxygenated water are created, through which the migratory fish, salmon and sea trout, will not penetrate until freshening floods arrive. It is feasible to prescribe certain general rules and to set up representative River Boards for each district.

SPECIAL SESSIONS ON JUTE

Two special sessions on Jute were arranged to be held at the Dundee Meeting. Only the first of these took place but the papers then given, and those which should subsequently have been given, have been collected and published in *The Journal of*

the Textile Institute, September 1939, Vol. XXX, No. 9, pp. P273–P399. The authors and titles are as follows :

Dr. S. G. Barker.—' The Science of Jute.'
Dr. W. G. Macmillan.—' Observations on the Swelling of Jute Fibres.'
Herbert L. Parsons.—' Chemistry in the Processing of Jute.'
D. Carter.—' The Dyeing of Jute.'
H. A. Elkin and W. A. S. White.—' Rot-proofing of Jute.'
R. S. Finlow, C.I.E.—' The Production of Jute.'
J. K. Eastham.—' Some Economic Problems of the Jute Industry.'
Alexander King.—' The Emulsification of Batching Oils.'

REPORTS OF RESEARCH COMMITTEES

SECTION A (MATHEMATICAL AND PHYSICAL SCIENCES)

SEISMOLOGICAL INVESTIGATIONS

FORTY-FOURTH REPORT of the COMMITTEE on Seismological investigations (Dr. F. J. W. WHIPPLE, Chairman ; Mr. J. J. SHAW, C.B.E., Secretary ; Miss E. F. BELLAMY, Prof. P. G. H. BOSWELL, O.B.E., F.R.S., Dr. E. C. BULLARD, Dr. A. T. J. DOLLAR, Dr. A. E. M. GEDDES, O.B.E., Prof. G. R. GOLDSBROUGH, F.R.S., Dr. WILFRED HALL, Mr. J. S. HUGHES, Dr. H. JEFFREYS, F.R.S., Mr. COSMO JOHNS, Dr. A. W. LEE, Prof. E. A. MILNE, M.B.E., F.R.S., Prof. H. H. PLASKETT, F.R.S., Prof. H. C. PLUMMER, F.R.S., Prof. J. PROUDMAN, F.R.S., Dr. A. O. RANKINE, O.B.E., F.R.S., Rev. C. REY, S.J., Rev. J. P. ROWLAND, S.J., Prof. R. A. SAMPSON, F.R.S., Dr. F. J. SCRASE, Capt. H. SHAW, Sir FRANK SMITH, K.C.B., C.B.E., Sec.R.S., Dr. R. STONELEY, F.R.S., Mr. E. TILLOTSON, Sir G. T. WALKER, C.S.I., F.R.S.).

MEETING OF THE COMMITTEE.

THE Committee met once during the year, on October 28, 1938. The Annual Grant of £100 from the Caird Fund was allocated to the University Observatory, Oxford, for work on the International Seismological Summary. Expenditure on various objects from the Gray-Milne fund was authorised, the principal item being the purchase of a new seismograph, to be sent on loan to Fiji. It was announced that a gentleman, who wished to remain anonymous, had offered a donation to the Committee to cover, for some years, the payment of an honorarium to the keeper of the shock recorder at Dunira. The offer was gratefully accepted.

THE GRAY-MILNE FUND.

The accounts for the year are reproduced below. The income of the fund has gone down again, no dividend having been paid on preference shares by the Canadian Pacific Railway.

Expenditure on the Milne Library includes the purchase of *Practical Seismology*, by L. Don Leet, and of *Earthquakes and other Earth Movements*, by J. Milne and A. W. Lee.

The *Tables of Geocentric Co-ordinates* were referred to in last year's report and were circulated in the autumn.

Gray-Milne Fund.

	£	s.	d.		£	s.	d.
Balance, July 1, 1938	204	7	10	Milne Library	2	16	6
Trust Income	46	14	10	Insurance		15	0
Bank Interest		17	7	Tables of Geocentric Co-ordinates (computing and printing)	67	14	9
Donation	50	0	0	Milne-Shaw Seismograph	80	0	0
				Clock	29	10	0
				British Earthquake Inquiry	34	12	5
				Shock Recorder (installation and maintenance)	13	8	9
				Balance, July 10, 1939	73	2	10
	£302	0	3		£302	0	3

Seismographs.

In 1937 it was learned that the newly formed Seismological Committee of the Australian and New Zealand Association for the Advancement of Science was anxious for the installation of a modern seismograph in Fiji in place of the Milne instrument which had been in use for many years. This Committee, being aware of the great importance of additional seismographic stations in the Pacific, decided to obtain a Milne-Shaw seismograph for loan to the Fiji Government, if arrangements could be made for the operation of the instrument at Suva. The offer of the loan was duly accepted. The seismograph was despatched at the beginning of June 1939, together with a clock, a 'seconds regulator' of high precision, supplied by Mr. Shaw. The records from the seismograph are to be forwarded to the Dominion Observatory, Wellington, New Zealand, for interpretation.

It is of interest to note that Fiji is in a region which has assumed a new importance in seismological investigations with the development of knowledge of deep-focus earthquakes. In a paper published in 1937 on the depth and geographical distribution of deep-focus earthquakes, by B. Gutenberg and C. F. Richter, the area immediately S.E. of Fiji is credited with 15 earthquakes with foci at depths of at least 500 km., the total number of such earthquakes identified in the whole world being 58. Of these 14 were in South America, 15 in the East Indies, and the other 14 near Japan. The records from the new station will be a useful addition to the material for the study of the earthquakes of this very interesting class.

The instrument at Suva is the seventh Milne-Shaw seismograph belonging to the British Association. The others are on loan to the seismological stations at Oxford (2), Edinburgh, Perth (W. Australia), and Cape Town (2).

It is opportune to mention that a minor improvement has been introduced in the later Milne-Shaw seismographs. It will be remembered that in this type of instrument the magnification is obtained by a rotating mirror deflecting a beam of light. The mirror lever is coupled to the outer end of the pendulum by means of a very light coupler, whose iridium points rest in agate cups on lever and pendulum. When an earthquake occurs in the vicinity of the instrument and the movement is severe, the points are liable to be forced out of the cups and the seismograph is then put out of action until it is visited by the observer. This happened, for instance, with nearly all the seismographs in India on the occasion of the great

Behar earthquake. The difficulty has been met by surrounding the agates with light aluminium bands, which virtually make the shallow cups into deep ones.

It has always been assumed that the free motion of the Milne-Shaw seismograph was in accordance with the mathematical theory of damped periodic motion and that the period could be determined by removing the damping magnets. In view of certain well-known observations made on Galitzin pendulums by Prince Galitzin and by M. A. Somville, it was desirable to test the Milne-Shaw. Dr. A. E. M. Geddes reports that he has been making observations with the instruments at Aberdeen, using the method developed by Dr. Lee at Kew Observatory. The agreement with the theory is very satisfactory. There is some indication that the period of the pendulum is slightly increased by the introduction of damping, but the effect is only of the order of the tenth of a second. Dr. Geddes suggests that the aluminium boom of the pendulum may be somewhat paramagnetic.

The Jaggar shock recorder made for the Committee at Bristol under the supervision of Dr. C. F. Powell was installed at Dunira, in Perthshire, in September 1938. The Committee is indebted to Dr. A. T. Dollar for making all arrangements for the operation of the instrument, as well as to Mr. W. G. Macbeth for providing the site, and to Mr. R. White and his assistants for constant attention. As will be seen from Dr. Dollar's summary, no fewer than six tremors, provisionally regarded as small local earthquakes, have been recorded. None of these tremors is known to have been felt by anyone. It was not expected that the shock recorder would respond to distant earthquakes, and, as a matter of fact, there were no disturbances recorded at Kew Observatory at any of the times of these tremors at Dunira. Three of the tremors occurred in the small hours of the morning, so it is unlikely that they were due to any human activity.

In the remarks on the history of seismic disturbances in last year's Report, it was stated in error that one of Forbes's inverted pendulums was in the Royal Scottish Museum at Edinburgh. Actually the instrument in question is in the Natural Philosophy Museum of Edinburgh University. Prof. Barkla has kindly offered to have a photograph taken of this pioneer seismoscope.

The International Seismological Summary.

Since the inauguration of the *International Seismological Summary* in 1922, it has been produced by the University Observatory, Oxford, with the assistance of the International Seismological Association, International Union for Geodesy and Geophysics, and of the British Association. The policy of the I.S.A. with regard to the Summary has been discussed at the triennial meetings, but there has been little opportunity for the discussion of technical details. The appointment, by the President of the I.S.A., Captain N. H. Heck, of an Advisory Committee, to formulate the policy of the Association is therefore to be welcomed. The chairman of the Committee is Dr. S. W. Visser, who is well known for his work on the earthquakes of the East Indies, and, on the nomination of the Council of the British Association, Dr. Harold Jeffreys, F.R.S., has been appointed a member. Among the important matters which have to be considered before the meeting of the I.S.A. at Washington in September, are the adoption of geocentric co-ordinates in the calculation of distances and the introduction of new standard tables of reference.

The Committee.—By the death of Sir Frank Dyson the Committee has lost one of the oldest members. He had served since 1912. His wise counsel was much appreciated by his colleagues on the Committee.

During the year a considerable number of papers on seismology have been published by members of the Committee.

Dr. H. Jeffreys has been active in the discussion of the transmission times of earthquake waves. He contributes a short account of his work to this report. He

has also contributed to the series ' Ergebnisse der Kosmischen Physik,' an account of deep-focus earthquakes and their bearing on the theory of the mechanism of earthquakes. In this memoir new views as to the nature of isostatic compensation are developed.

Dr. R. Stoneley has discussed two double earthquakes and has also analysed the material provided by fifteen well-observed earthquakes to ascertain the extent to which Rayleigh waves and Love waves can be distinguished in the records. He finds significant differences in the relative frequency in different shocks and considers that these imply differences in the types of initial movement at the foci.

Mr. E. Tillotson has reported the results of an examination of the seismograms for two earthquakes, with a view to the identification of the phases PcP and ScS. These waves, which are reflected by the earth's core, are generally regarded as very difficult to detect, but Mr. Tillotson believes that he has traced them with great regularity and consistency.

A book by Dr. A. W. Lee, *Earthquakes and other Earth Movements*, has been published by Messrs. Kegan Paul, Trench, Trubner & Co., as the seventh edition of the work by John Milne with the same title. The first edition appeared in 1883 and the sixth in 1913. The great advance in seismology in the last quarter of a century is illustrated by the extent to which rewriting was necessary. This advance is due in no small measure to the work inaugurated by Milne himself. A *Geophysical Memoir*, by Dr. Lee, on Seismology at Kew Observatory, has also been published during the year. In addition to a description of the installation of the instruments in the new seismograph house the memoir contains discussions of theoretical questions connected with the operation of Galitzin seismographs.

Reports by Miss Bellamy on seismological work at the University Observatory, Oxford, and by Dr. Dollar on the activities of the ' British Earthquake Enquiry ' are to be found below.

Notes on the Work at Oxford.

By Miss Ethel F. Bellamy.

Since the last British Association Seismological Report the following publications have been distributed :

I.S.S. 1933. January to September. J. S. Hughes and Ethel F. Bellamy.

Geocentric Direction Cosines of Seismological Observatories. L. J. Comrie and H. Jeffreys.

Tables for Converting Geographic into Geocentric Angular Distances. K. Bullen.

The Forty-third Seismological Report of the Committee.

The last quarter (1933) of the *I.S.S.* is in print, and the manuscript is prepared to the end of April, 1934.

It is still regrettable that stations do not send their seismological readings earlier. Many are more than five years in arrears. If stations would send manuscript copies instead of waiting to print, it would facilitate the work at Oxford considerably, since late readings frequently make it necessary to recompute an epicentre. Moreover, the absence of all returns from certain stations makes the *I.S.S.* incomplete.

During the year two Mollweide Projection maps, centred on 160° longitude, have been prepared : one for deep-focus epicentres (*Nature*, Vol. 143, p. 504), and the other for all epicentres used in the *I.S.S.* 1913–33. Copies of these maps are being sent to Washington for the meeting of the International Union of Geodesy and Geophysics in September. It was made possible to use this projection through the courtesy of the American Museum of Natural History, New York.

It has been our custom to issue a ' Catalogue of Earthquakes ' at approximately five-yearly intervals. As this Catalogue is prepared on the completion of each year,

it has been decided to publish each year as a unit under the title, 'Index to the International Seismological Summary.' It can then either be bound with the *I.S.S.* (as it is none other than an index to that publication) or allowed to accumulate for another five years.

During the year Mr. R. E. Ockenden has given some valuable books to the John Milne Library and Dr. J. Coggin Brown has presented copies of his papers on Indian earthquakes: we are very grateful for these and other reprints received.

A card index has been made of the John Milne Library, and this is now in course of preparation, with a view to having a catalogue printed for future distribution. Besides being a permanent record, this will be found useful for those wishing to use the Library.

Report of the British Earthquake Inquiry for the Year 1938–39.

By Dr. A. T. Dollar.

During the year July 1, 1938, to June 30, 1939, a Jaggar Earthquake Shock Recorder was installed at Dunira, Comrie, two reports of minor British Isles earth tremors were investigated and additional material collected for the catalogue of British Earthquakes noticed between January 1, 1916, and October 1, 1935. In the latter connection useful information was extracted from files of the *Scotsman* for comparison with data obtained from other sources.

Early in October 1939, the recording centre of the British Earthquake Inquiry will be moved from Emmanuel College, Cambridge, to the Geology Department, University of Glasgow, where Dr. Dollar will continue to assemble and analyse seismic information as at the former address.

The 287 permanent voluntary reporters were increased by 34 during the year, but their general distribution in Great Britain, the Irish Free State and the Channel Islands has remained substantially the same. A campaign for increasing the number and representative character of reporters is being prepared and will be launched shortly. To this end further contacts have been made with the British Broadcasting Corporation and other bodies. The third edition of the questionnaire has proved satisfactory after being in use for nearly thirteen months.

Seismic Data gathered between July 1, 1938, *and June* 30, 1939.

Since July 1, 1938, information has been collected about the following tremors felt in the British Isles. It would seem likely that both of these were due to subterranean subsidences, possibly associated with mine-workings. No undoubted earthquakes have been reported.

Subsidences and Mine-shakes.

November 12, 1938. Brierley, Yorkshire.
December 18, 1938. Porth, Glamorganshire.

The Jaggar Shock Recorder at Dunira, Comrie.

Between September 14 and 15, 1938, Dr. Dollar installed at Dunira, Comrie, Perthshire, the Jaggar Earthquake Shock Recorder, which was made for the Committee at Bristol, under the supervision of Dr. C. F. Powell.

Through the courtesy of Mr. W. G. Macbeth, of Dunira, the instrument was housed on his estate, and has been operated since that time by Mr. R. White, his head gardener.

Three sites for the Recorder were considered, of which one was rejected on account of traffic vibration, and another because of the presence of fluctuating temperatures and humidities.

The small croquet house in which the instrument was finally erected, is situated at the point Long. 4° 2′ 41″ W., Lat. 56° 23′ 19″ N., in a quiet garden overlying metamorphic Highland rocks which are penetrated by igneous injections. The site is about 120 ft. due S. of the S.E. front of Dunira House, and nearly three miles N.N.W. of the Highland Boundary Fault system. The croquet house has a tiled roof, stone walls and a concrete floor. The walls are built against a thick dyke of fresh dolerite, and the north wall is in direct contact with this dyke.

The house is dry, free of disturbances due to draughts, insects and small animals, and vibrations arising from human beings and road or railway traffic. Neither the temperature nor the humidity of the interior is subject to marked variation.

The instrument stands in the N.W. corner of the building where it is screwed to four wooden plugs driven into solid dolerite through the thin N. wall.

The pendulum oscillates in a vertical plane oriented N. 76° E. (Geog. bearing), and is adjusted to a period of nearly one second. Damping is provided by a metal fin dipping into a bath of oil.

Initial difficulties were encountered in connection with the motion of the clock on its supporting rails, but these were overcome, and it was then regulated until the disk completed one revolution in thirty minutes. Arrangements were made that Mr. White should replace the smoked disks every twenty-four hours, fix the same and forward a group of them to Dr. Dollar at intervals of about one month. However, since September 15, 1938, certain interruptions in the series of daily records have been caused by minor adjustments of the mechanism and also by the illnesses of Mr. White between November 2 and December 8, 1938, and from early in June 1939 until the present date. On the disks received, numerous small tremors were recorded but of these only six were of sufficient magnitude to be of interest. Their dates and times were as follows :

1938	October 15	14h. 51m.	G.M.T.
1938	November 12	17h. 59m.	,,
1939	January 23	2h. 16m.	,,
1939	May 26	9h. 54m.	,,
1939	May 31	2h. 12m.	,,
1939	June 11	5h. 16m.	,,

If the instrument is maintained at Dunira in future, regular personal supervision of its operation will be simplified by the presence of Dr. Dollar at Glasgow.

Thanks are due to Mr. Macbeth for the generous hospitality and assistance which he extended to Dr. Dollar during the installation of the Recorder.

Transmission Times.

By Dr. Harold Jeffreys, F.R.S.

The work on the Japanese deep-focus earthquakes, mentioned in last year's Report, has been completed. It led to the result that the time-curves for P and S near 20° agree best with the hypothesis of an increase of velocity with depth sufficiently rapid to produce a loop in the time-curve, but not amounting to a definite discontinuity. The data for S at short distances led to a satisfactory determination of its times, corresponding to distances up to 20° in normal earthquakes. These earthquakes were used to reconstruct the S and SKS times completely, and pP and sS were used to give a new datum about the thicknesses of the upper layers, which replaces the less satisfactory one derived from near earthquakes. The present estimates are 15 $\pm$ 3 km. for the upper layer ; 18 $\pm$ 4 km. for the intermediate one.

These results have made it possible to adapt all phases to a surface focus, with an uncertainty under a second. Some supplementary information from normal earthquakes was used to extend the S and SKS tables. At this stage it appeared worth

while to calculate the velocity distributions. Times of reflexions at the core, given by Scrase, Stechschulte, and Gutenberg and Richter, have been used to find the radius of the core, which is 3473 $\pm$ 4 km. This result being combined with the times of PKP and SKS, times in the core itself were found and the velocity calculated for radii down to 0·40 of the core radius. At that point there is a new complication, since the opinion of Lehmann, Gutenberg and Richter, that what has been considered to be diffracted PKP at distances less than 142°, is really reflected or strongly refracted at an inner core, seems to be thoroughly substantiated. This complication prevents the solution from being taken to greater depths without some further assumption. That of reflexion has been adopted ; on it the velocity must fall a little with depth between radii 0·40 and 0·36 of the radius of the core, then again rising suddenly when the inner core is entered. The velocity of the inner core is nearly uniform.

Times have been worked out for all the principal core phases, and it is suggested that the results may now be generally adopted as a standard of comparison. Means are provided for correcting for focal depth in all cases.

Reappointment of the Committee.

The Committee asks for reappointment and for the renewal of the grant of £100 from the Caird Fund.

MATHEMATICAL TABLES

REPORT of COMMITTEE on Calculation of Mathematical Tables (Prof. E. H. Neville, Chairman ; Dr. A. J. Thompson, Vice-Chairman ; Dr. J. Wishart, Secretary ; Dr. W. G. Bickley, Prof. R. A. Fisher, F.R.S., Dr. J. Henderson, Dr. E. L. Ince, Dr. J. O. Irwin, Dr. J. C. P. Miller, Mr. Frank Robbins, Mr. D. H. Sadler, Mr. F. Sandon, Mr. W. L. Stevens, Dr. J. F. Tocher and Mr. M. V. Wilkes).

General activity.—Eight meetings of the Committee have been held, in London.

The grant of £200 has been expended as follows :

	£	s.	d.
Wages and insurance of computer	156	14	8
Calculations for Bessel functions of order greater than one	25	0	0
Calculations for Airy Integrals	5	0	0
Provision of table and chair	4	15	0
Secretarial and miscellaneous expenses	8	10	4

Personnel.—During the year two members have been added to the Committee in the persons of Mr. F. Sandon and Mr. M. V. Wilkes. The Committee was glad to welcome to certain of its meetings Prof. D. H. Lehmer, of the University of Lehigh, Pa., U.S.A., who has taken a great deal of interest in the work of the Committee during his stay in this country.

Cambridge Meeting, 1938.—A group of papers, on problems related to the production of mathematical tables, was given by Dr. Bickley, Dr. Miller and Dr. Thompson in Section A, Department of Mathematics, and the Committee's National machine, after certain preliminary difficulties of organisation, was successfully demonstrated, as part of a general exhibition of calculating machines. A talk on the machine was given by Mr. D. H. Sadler, while the Committee's computer, Mr. H. O. Hartley, was in attendance throughout the meeting to give demonstrations.

Employment of computers.—Mr. H. O. Hartley, who was appointed to the post of computer on June 13, 1938, resigned on September 10, 1938. He was succeeded by Mrs. R. St. H. Tysser, who commenced work on October 10, 1938. Her work is mainly on the National machine, but one of the Committee's Brunsviga machines is now housed in the Galton Laboratory, being required for ancillary calculations. The Committee desires to record its indebtedness to Prof. R. A. Fisher for kindly placing facilities for the accommodation of computer and machines in the Galton Laboratory at its disposal, and for allowing the Committee to meet on the premises. The Committee has acquired a table and chair for the use of its computer. The other two calculating machines are in the charge of Dr. Thompson and Dr. Miller, and have been fully used. The voluntary services of Mr. C. E. Gwyther are again acknowledged with gratitude, and the Committee records its appreciation of the continued facilities offered by the Mathematical Laboratory of the University of Liverpool for computations carried out under Dr. Miller's direction.

Bessel Functions.—

$Y_n(x)$. The calculations of $Y_n(x)$ are now completed for $n = 0(1)21$, $x = 0{\cdot}0(0{\cdot}1)21{\cdot}0$ to 13 figures, and $y_n(x) = x^n Y_n(x)$ is also complete to 13 figures as far as required for tabulation. Part of the $y_n(x)$ table will require interpolation to interval $0{\cdot}01$.

$I_n(x)$. The following material is ready for National Machine operations :

$i_n(x) = x^{-n} I_n(x)$, $n = 2(1)10$, $x = 0{\cdot}0(0{\cdot}1)5{\cdot}0$, to be differenced, then interpolated to interval $0{\cdot}01$ and copy prepared ;

$$
\begin{aligned}
i_n(x) \qquad n &= 11(1)20,\ x = 0{\cdot}0(0{\cdot}1)5{\cdot}0,\\
n &= 6(1)10,\ x = 5{\cdot}0(0{\cdot}1)10{\cdot}0,\\
n &= 11(1)15,\ x = 5{\cdot}0(0{\cdot}1)10{\cdot}0,\\
n &= 16(1)20,\ x = 5{\cdot}0(0{\cdot}1)15{\cdot}0,
\end{aligned}
$$

to be checked and copy prepared.

The multiplications involved in calculating a second auxiliary function $e^{-x} I_n(x)$ to 11 significant figures are now being carried out for (i) $x = 15{\cdot}0(0{\cdot}1)20{\cdot}0$, $n = 2(1)20$, (ii) $x = 10{\cdot}0(0{\cdot}1)15{\cdot}0$, $n = 2(1)15$, (iii) $x = 5{\cdot}0(0{\cdot}1)10{\cdot}0$, $n = 2(1)5$. The National Machine will then check and make copy.

$K_n(x)$. The calculations to 12 or 13 figures for $n = 0(1)20$ and $x = 0{\cdot}0(0{\cdot}1)18{\cdot}5$ have now been completed, and for $x = 18{\cdot}5(0{\cdot}1)20{\cdot}5$ are in progress. The auxiliary functions (i) $k_n(x) = x^n K_n(x)$, (ii) $e^x K_n(x)$, for $x > 5{\cdot}0$ are now being prepared.

Zeros of $J_n(x)$, $n > 1$, $x \ngtr 25$, have been computed to 12 decimals by inverse interpolation, and also larger zeros of $J_2(x)$ and $J_3(x)$ by use of the McMahon formula. The Committee is indebted to Mr. S. Johnston for the calculation of these zeros.

Table of Powers.—The scope of this table, referred to in previous Reports, has been extended to include the powers x^n for

$$
\begin{aligned}
x &= 250 \text{ to } 299,\ n = 13 \text{ to } 20\ ;\\
x &= 1050 \text{ to } 1099,\ n = 2 \text{ to } 12\ ;
\end{aligned}
$$

and a paging scheme for the tabular matter has been prepared. The extra values have been computed and checked, and the copy prepared by summation on the National machine. The complete copy of the Tables is now ready, and the preparation of the Introduction is in hand.

Airy Integral.—Some delay has arisen in the preparation of this table, owing to computational difficulties in connection with certain auxiliary functions; most of these have now been overcome. The first fifty zeros of $Ai(x)$ and $Ai'(x)$, with corresponding values of $Ai'(x)$ and $Ai(x)$, have been computed. At the suggestion of Dr. H. Jeffreys, a table of the second solution $Bi(x)$ of the differential equation $y'' = xy$ has been prepared for inclusion in the part-volume, covering the range $x = -10{\cdot}0(0{\cdot}1)+2{\cdot}5$, to 8 decimal places.

Legendre Functions.—Tables of these functions were prepared some years ago under the supervision of Dr. Comrie while he was Secretary of the Committee. As implied in earlier Reports, difficulties were encountered in printing; Dr. Thompson has added during the year the values of $P_{10}(x)$, $P_{11}(x)$ and $P_{12}(x)$ for the range $x = 0{\cdot}00(0{\cdot}01)1{\cdot}00$, and the tables are now being published as a part-volume under his editorship.

Sheppard Tables.—The Committee's seventh volume, containing certain tables of the probability integral computed by the late Dr. W. F. Sheppard, and completed by the Committee, has now been published under the editorship of Dr. Irwin. In issuing this volume the Committee believes that the completion and publication of his tables of the probability integral constitute just that memorial to Sheppard's labours in the field of mathematical statistics which he would himself most greatly have appreciated.

Glaisher's Tables.—The Cambridge Philosophical Society has for long had in its possession certain tables in the theory of numbers, computed by Glaisher in 1882, and destined at that time for the *Transactions*, now no longer published. The main table gives, for $n = 1(1)10000$, (a) the prime factors of n, (b) the number of numbers not exceeding and prime to n, (c) the number of divisors of n, and (d) the sum of the divisors of n. Three inverse tables give the values of n, up to 3000, corresponding to (b), (c) and (d), of the main table as arguments. The Society has now requested the Committee to take over the tables for completion and publication, and this, in view of the recommendations made as to the value of these tables to workers in the theory of numbers, the Committee agreed to do. Most of the material already exists in the form of stereo plates. Authority has been obtained to proceed with the publication, as one of the Committee's series of volumes, the cost to be met out of the Cunningham Bequest. Prof. D. H. Lehmer has given the Committee considerable assistance in planning the work, and in devising checks to be employed to ensure that the tables are accurate, and he has written an introduction to the Tables. The work is proceeding under the editorship of Dr. Wishart. The main table has been completely checked, and the inverse tables have been extended as far as the main table will carry them in a complete form.

Miscellaneous.—The Committee has remained in touch with the project for the computation of mathematical tables, which is being conducted by the Works Progress Administration for the City of New York, and information has been exchanged relating to the work in progress on both sides of the Atlantic. A number of inquiries has been dealt with on questions relating to the availability of mathematical tables of one sort or another. The Committee has made arrangements to preserve manuscripts of unpublished computations in such a form as to be intelligible if occasion for their use should arise in the future.

Reappointment.—The Committee desires reappointment, with the addition of Prof. L. M. Milne-Thomson, and with a grant for general purposes of £200.

SECTIONS A (MATHEMATICAL AND PHYSICAL SCIENCES) AND C (GEOLOGY)

THERMAL CONDUCTIVITIES OF ROCKS

REPORT of COMMITTEE appointed to direct determination of the thermal conductivities of rocks in mines or borings where the temperature gradient has been, or is likely to be, measured (Dr. Ezer Griffiths, F.R.S., Chairman; Dr. D. W. Phillips, Secretary; Dr. E. M. Anderson, Dr. E. C. Bullard, Prof. W. G. Fearnsides, F.R.S., Prof. G. Hickling, F.R.S., Prof. A. Holmes, Dr. Harold Jeffreys, F.R.S., Dr. J. H. J. Poole).

Dr. Benfield has made measurements on the thermal conductivity of specimens of rock taken from the cores of borings at Hankham in Sussex, at Holford in Cheshire and at Boreland in Fife. Temperature measurements are available for the first two holes, and it is hoped to obtain them for the third when drilling is completed. The conductivities obtained at Boreland can be combined with the temperature measurements made by the former B.A. Committee in other holes in similar strata. A paper describing this work has been submitted to the Royal Society. In this paper heat flows for 5 bores are deduced, the mean is $0 \cdot 98 \times 10^{-6}$ cal/cm^2 sec. This is probably some 30 per cent. less than the equilibrium value owing to the effect of the Ice Age.

Dr. Bullard, working at the Bernard Price Institute in Johannesburg, has made conductivity observations on 49 rock specimens taken from the cores of deep bores in South Africa. Numerous temperature measurements have been made by Dr. Krige, of the South African Geological Survey, and by Mr. Weiss. These measurements are extremely detailed, as many as 25 temperatures having been taken at different depths in a single hole. The exceptional number and quality of the temperature measurements suggested that these bores provided an opportunity to test the methods by which the heat flow is obtained and to investigate possible sources of error. The results of these investigations were :—

1. That the divided bar method applied to rocks gives conductivities with an accuracy of about 5 per cent. This accuracy is estimated from the agreement obtained with three specimens made from the same sample. The errors are largely random, and are reduced by taking the mean of a number of samples.

2. That the conductivity of the rocks in a bore hole varies by considerably more than the errors of measurement, even in apparently homogeneous rocks. For example, specimens made from a bore traversing 4,000 ft. of Transvaal Dolomite gave conductivities varying from $0 \cdot 0096$ to $0 \cdot 0120$ cal/cm. °C. sec.

3. If holes in Dolomite are excluded the measured heat flow does not vary with depth by more than a few per cent. What variation there is can be accounted for by the uncertainty in the mean conductivity due to the limited number of samples studied. This is a valuable confirmation of the satisfactoriness of the temperature and the conductivity measurements. The variation in Dolomite is probably due to the circulation of water in fissures.

4. The heat flow varies between different bores by amounts of the order of 30 per cent. Variations of this order are to be expected, due to the disturbance of the heat flow by geological structures.

The mean heat flow obtained in this work is $1 \cdot 16 \pm 0 \cdot 09 \times 10^{-6}$ cal/cm^2 sec, the standard error being derived from the differences between the bores. The differences between the bores are almost entirely real differences, the experimental errors only making a relatively small contribution.

The heat flows in England and South Africa are therefore equal within the un-

certainties produced by the variation between individual bores. This is a striking result since in most of the English bores the temperature increases by 1° C. for every 100 ft. increase of depth, whilst on the Rand the increase is 1° C. for about 350 ft. The Witwatersrand quartzites are much better conductors of heat than the shales and mudstones traversed by the bores in which most of the temperature measurements in Great Britain have been made ; and the heat flow, which is the product of the temperature gradient and the conductivity, is the same in both places.

Dr. Krige is continuing his temperature measurements in bores in South Africa, and Dr. Cooper is making conductivity determinations on samples from the cores. Two instruments for this purpose were left in Johannesburg by Dr. Bullard. One of these uses circular specimens 1⅝ in. in diameter (the same diameter as most of the cores), and the other semicircular specimens. The latter is used when the core has been split for assay.

Pieces of core from Persia have been received from the Anglo-Iranian Oil Co.; it is hoped that it will be possible to measure the conductivities during the next year.

Fig. 1 gives a summary of the conductivities measured during the year ; the line marked 'shale' includes mudstones, 'fakes,' marl and fireclay. The 'lava' is Ventersdorp.

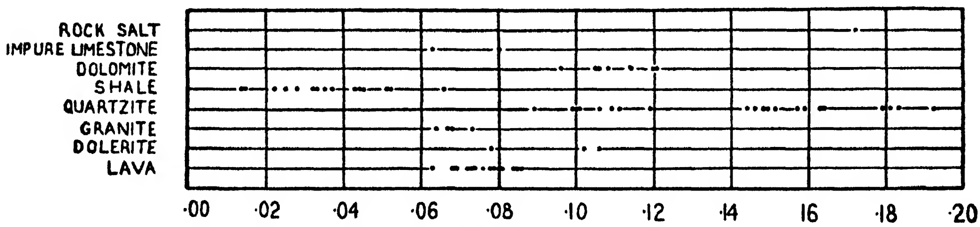

FIG. 1.—Thermal conductivities measured during the year 1938–9 in cal/cm° C. sec.

SECTIONS A (MATHEMATICAL AND PHYSICAL SCIENCES) AND J (PSYCHOLOGY)

QUANTITATIVE ESTIMATES OF SENSORY EVENTS

FINAL REPORT of the COMMITTEE appointed to consider and report upon the possibility of Quantitative Estimates of Sensory Events (Prof. A. FERGUSON, Chairman ; Dr. C. S. MYERS, F.R.S., Vice-Chairman ; Mr. R. J. BARTLETT, Secretary ; Dr. H. BANISTER, Prof. F. C. BARTLETT, F.R.S., Dr. WM. BROWN, Dr. N. R. CAMPBELL, Mr. K. J. W. CRAIK, Prof. J. DREVER, Mr. J. GUILD, Dr. R. A. HOUSTOUN, Dr. J. O. IRWIN, Dr. G. W. C. KAYE, O.B.E., Dr. S. J. F. PHILPOTT, Dr. L. F. RICHARDSON, F.R.S., Dr. J. H. SHAXBY, Mr. T. SMITH, F.R.S., Dr. R. H. THOULESS, Dr. W. S. TUCKER, O.B.E.).

THE Committee was originally appointed at York in 1932 after Sections A and J had held a joint session dealing with the problem. It has been reappointed each year since, and after presenting brief interim reports in the earlier years was able to make a long interim report last year (*Report*, 1938, pp. 277–334). This report contains (*a*) an historical statement ; (*b*) a summary of recent experimental work ; (*c*) a statement arguing that sensation intensities are not measurable ; (*d*) various notes on this statement, and (*e*) a statement arguing that sensation intensities are

measurable. It concluded by ' asking for reappointment to consider whether the views put forward are, or are not, irreconcilable.'

After the last reappointment the Committee met on two occasions, discussed various attempts to secure agreed conclusions, and appointed a Sub-Committee consisting of Prof. Ferguson (Chairman) ; Dr. N. R. Campbell, Mr. K. J. W. Craik, Dr. J. O. Irwin and Mr. R. J. Bartlett (Secretary) ; to prepare a draft report in the light of these discussions. This Sub-Committee met on four occasions, and its draft was considered by the full Committee at a third meeting held on June 1, when it was agreed to report as follows :

1. In their early discussions the Committee found themselves unable to agree on the meaning of such terms as ' measurement ' or ' quantitative estimate.' Some members held that such terms should not be used in any sense other than that in which they are used in physics. Others held that, if such terms were to be used in any but the physical sense, the other sense should be first defined ; any attempt at definition was found to raise questions on which the Committee differed.

The Committee have found it possible eventually to state their conclusions in terms that all of them could accept ; but in doing so they have had to ignore the wording of their terms of reference. They believe that the problems they discuss in this report are indeed those on which their opinion was invited ; but they feel that they must open by stating in their own words what these problems are.

2. They believe that these may be suitably illustrated by the problems of describing and interpreting experiments on just perceptible differences (j.p.d.) and on equal appearing intervals (e.a.i.). One form of each of these experiments will be described briefly.

In one form of j.p.d. experiment a subject is presented with a stimulus A and told to choose another, B, just perceptibly different from it. He is then presented with C and told to choose another, D, just perceptibly different from it in the same direction, and so on.

In one form of e.a.i. experiment the subject is presented with three stimuli, P, Q, R, and told to choose another, S, such that the difference between R and S appears to him to be equal to the difference between P and Q.

3. The Committee agree that the consistency between the choices of a single observer or even between those of different observers, in suitable circumstances, is so great, both in j.p.d. and in e.a.i. experiments, that these choices represent scientific facts in the most complete sense. Any difference between members of the Committee concerns only the exact extent of the facts or the way in which they are most appropriately expressed. Accordingly it is unnecessary here to inquire more precisely into what are the ' suitable circumstances ' in which the admitted consistency can be obtained.

4. The stimuli are often (perhaps always) physical magnitudes that can be measured by recognised physical methods, whose validity is not in doubt. Thus they may be brightnesses of a surface or intensities of a note of given pitch. Then the results can be expressed, *at least partially*, as follows.

In a j.p.d. experiment, let I be the numerical value of one of the presented stimuli and I′ that of the stimulus chosen as just perceptibly different from it. Then we can plot I′ against I, or, if we prefer, $\delta I (= I' - I)$. It is agreed that the relation of I′ or δI to I is (in suitable circumstances) so smooth that if I′ (or δI) and I were numerals resulting from a physical experiment any competent physicist would feel justified in drawing a smooth curve through them and asserting that he had established a numerical law.

Weber's Law states that this smooth curve is a straight line which if produced would pass through the common origin of δI and I, so that $\delta I = kI$, and $I' = (k + 1)I$. It is agreed that there are circumstances in which this is true for a limited

range of stimuli ; but they are not universal ; in some circumstances some other smooth curve is indicated.

In e.a.i. experiments, let p, q, r, s, be the values of a set of stimuli P, Q, R, S. Then we can seek in an analogous manner a 'smooth relation' between p, q, r, s. But it is not likely to be found unless it is simple.

Fechner's Law states that $p/q = r/s$. It is agreed that there are circumstances in which this is true ; but they are not universal ; in some circumstances no simple relation can be found ; in others it can be found, but is not exactly that of Fechner.

When both Weber's Law and Fechner's Law are true, certain logical consequences can be deduced from their combination. It has been pointed out to the Committee that one of these consequences is that all equal appearing intervals contain the same number of just perceptible differences ; the Committee agree that this is a logical deduction from the two laws.

5. The relation between δI and I (or between p, q, r, s) can be transformed as any algebraical or graphical relation can be transformed. Thus, when a relation $\delta I = f(I)$ has been established, algebraically or graphically, it is always possible to calculate $L = \int_{I_0}^{I} \frac{du}{f(u)}$ and thus to establish a relation between the variables L and I. But such transformations neither add to nor subtract from the *facts* expressed by the relation between δI and I. They are of the same nature as the substitution of δI for I' in the original statement of the facts.

6. So far there is no dispute. But now the question arises whether the propositions of §§ 4, 5 express the facts *fully*.

It is said by some that they do not express the facts fully, because they do not introduce the conception of the intensity of a sensation, that is to say, something about a sensation that might be, and perhaps must be, represented by a numeral. These persons say that sensations have a quantitative aspect that demands expression in terms of such a conception.

7. This view will be illustrated by two extreme examples of it.

Fechner professed to prove that, in a j.p.d. experiment, the integral L is the true and necessary measure of the intensity of the sensation excited by stimulus I, so that the curve (or algebraic equation) relating I and L states a relation between the value of the stimulus and the intensity of the sensation excited by it. The Committee agree that his 'proof' is fallacious, and that no numerical relation between the value of the stimulus and the intensity of the sensation can be deduced logically from the equation $\delta I = f(I)$. But the admission that Fechner was guilty of a logical error does *not* imply that his conclusion, namely that L is the true and necessary measure of the intensity of the sensation evoked by stimulus I, is necessarily false.

Again if, in an e.a.i. experiment, the subject is told and agrees that numerals (say 1, 10, 50) are to be assigned to the intensities of the sensations excited by stimuli P, Q, R, it is said that he cannot describe his experience fully by merely choosing S, as described in § 2 ; in order to describe it fully he must assign some numeral to the intensity of the sensation evoked by S. Thus he may assign the numeral 59 and deny positively that the assignment of 51 would describe his experience.

It must be emphasised that this view, and especially as illustrated by the second example, is extreme, and that it is not entertained by all (or perhaps even most) of those who maintain that there is a quantitative aspect of sensation which is not expressed in §§ 4, 5.

8. Others hold a view that is extreme in the opposite direction. While they do not, of course, deny that subjects of psycho-physical experiments do experience what they say they experience, these persons consider that there is here a confusion between sensations and intellectual judgments, which are, in their opinion, false judgments.

They hold that the experience that there is something quantitative about sensations arises from the universal familiarity with physically measurable series, such as lengths or weights, and from the drawing of a false analogy between a series of sensations and one of these physically measurable series. They consider further that this tendency (namely to assume that, because sensations can be ordered in a series and relations between them recognised, sensations are measurable) is encouraged by the use of the word ' difference ' in instructing the subject ; he is thereby invited to associate the relation he is asked to observe with arithmetical difference, and therefore to associate numerals with his sensations. They say that, if the facts about sensations are to be discovered, the greatest care must be taken to avoid such associations ; and that if sufficient care were taken, it would be found that the only quantitative conceptions required to describe the facts fully are those appertaining to stimuli ; for sensations, the non-quantitative conceptions of order and relation would suffice.

9. An intermediate view is entertained by yet others. These persons, while they cannot accept the extreme views expressed in § 7, hold that a numerical scale of sensation intensities is required to express the regularity with which observers can bisect intervals of sensation intensity, and equate liminal or supraliminal intervals at different intensities. They consider that knowledge of physical magnitudes is not the basis of these judgments of equality and difference. They do not agree that the results of any psycho-physical experiment can be expressed fully in terms of stimulus intensities, since the particular intensity-changes or δI's which are being plotted are obtained only by reference to the sensations they evoke, and are based on the equality or inequality of these sensation intensities. This appears to them to show a relation between sensation intensities which demands numerical expression ; it does not seem merely a ' fact of psychological interest ' irrelevant to the quantitative expression of the data. They would admit that manipulation of sensation scales by those unused to them might lead to fallacious inferences, but consider that many physical scales are open to the same criticism ; it appears to indicate only the need for caution and understanding in using a scale, not the fallaciousness of the scale itself.

10. After examining these points of view the Committee are satisfied that no practicable amount of discussion would enable them to express an agreed opinion concerning these views. Some members, perhaps all, admit that their opinion might change if new facts were established ; but the facts that would be necessary for this purpose are not of the kind that can be established by any experimental method at present in general use. Accordingly the Committee abandoned their efforts to reach complete agreement, and invited any members who cared to do so to express their individual views more fully in statements to be appended to this agreed report. These statements, on which it is to be understood the Committee as a whole express no opinion, are grouped as follows :

Appendix I. On the Sone Scale.
Appendix II. On Measurement.
Appendix III. In defence of the Measurability of Sensation Intensity.
Appendix IV. In denial of the Measurability of Sensation Intensity.
Appendix V. On Mathematical Transformations and Sensation.

11. The word measurement does not appear in the Committee's terms of reference, but has figured largely in the Committee's discussions. Had a definition of measurement been found that gave satisfaction to all its members the task of the Committee might have been less recalcitrant and Appendix II need not have been written.

It is doubtful if its terms of reference would entitle the Committee to embark upon a discussion of the problem even if there were time at its disposal, but it would place on record that some members of the Committee are of opinion that the problem

of what constitutes valid measurement might with advantage be explored by a Committee covering a wider range of sections than the two more immediately concerned with this present report. Other members, however, are of opinion that no useful purpose could be served by such a Committee.

Appendix I.

On the Sone Scale.

The Sub-Committee was of opinion that the position would be made clearer if the points of view expressed in §§ 7, 8 and 9 were illustrated by reference to some definite proposal for establishing a numerical scale of sensation intensities. They chose for this purpose the Sone scale of loudness as expounded in *Hearing: Its Psychology and Physiology*, by Stevens and Davis, and divided between themselves the task of setting out the three points of view.

The Committee, while agreeing that such illustration was of assistance, decided that it would be best for the results of this section of the work of the Sub-Committee to appear in the Appendix as signed contributions.

A brief statement of the Sone scale is followed by three sections setting out the work of the Sub-Committee, and an additional contribution on the Sone scale from another member of the Committee.

A. *By Mr. K. J. W. Craik.*

The Sone scale is based on the following three methods of subjective estimation:

(1) Fractionation of loudness, i.e. adjustment of one tone till it sounds half, or one-tenth, as loud as another.

(2) Comparison of monaural and binaural loudness. A tone presented first to both ears and then to one appears to the observer to be half as loud in the second case, 'half' having the same meaning as in judgments of fractionation.

(3) A similar judgment of 'half as loud' can be obtained by presenting two tones of widely different frequencies in one ear, and then presenting one of the tones alone.

The curves shown in Fig. 41 of Stevens and Davis can then be drawn, showing as ordinate the intensity in db. of a tone, T_1, which sounds half or one-tenth as loud as another tone, T_2, whose intensity in db. is given by the abscissa. Then (to quote Stevens and Davis, p. 117): 'From the data in Fig. 41 we can proceed graphically to define an intensive loudness function satisfying the criteria laid down for an acceptable loudness scale. . . . This function is the one whose value at any given intensity is proportional to the subjective loudness produced by a tone of that intensity. First, we fit a curve to the data obtained by the "halving procedures," giving special weight to the points determined by the monaural-binaural method. Then we assign the arbitrary number 1 to the intensity of 40 db. above threshold and read on the ordinate scale the intensity of the tone which sounds half as loud, and which, therefore, receives the number 0·5. After repeating this procedure both above and below our starting-point at 40 db., we can plot the function for the 1,000-cycle tone, as shown in Fig. 43. This function, then, satisfies the criterion that any value N stands for a tone which appears to a normal observer half as loud as that represented by the number 2N—at least within the limits of experimental error. Had we used, in an analogous manner, the curve in Fig. 41 representing a tenfold reduction, we should have obtained a very similar function.' The loudness to which the number 1 was arbitrarily assigned is called a 'sone.' [1]

[1] The figures in this Appendix are reproduced from *Hearing*, by Stevens and Davis, by permission of the authors and of the publishers, Messrs. John Wiley & Sons, Inc., New York.

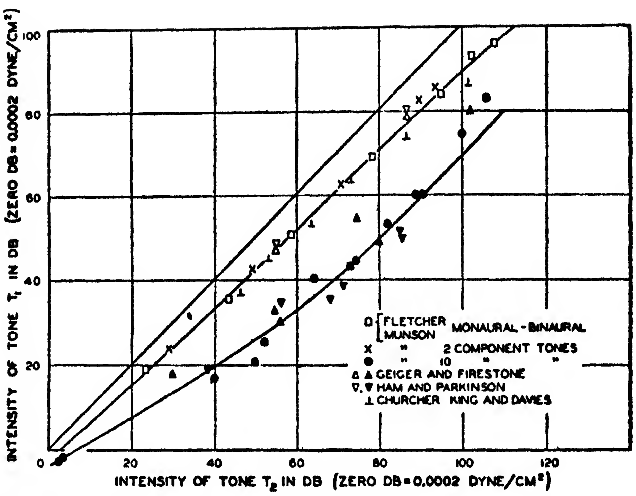

FIG. 41. The ordinate shows the intensity at which a tone (T_1) sounds half as loud (open figures) or a tenth as loud (solid figures) as another tone (T_2) whose intensity is given by the abscissa.

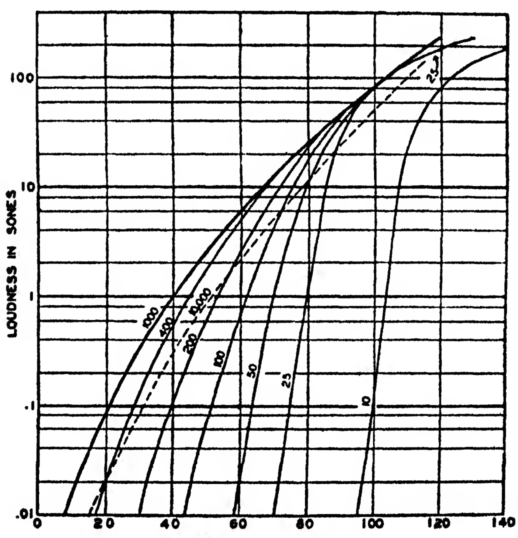

FIG. 43. The loudness-function. Showing how the perceived loudness of various tones depends upon the intensity of the stimulus. Frequency is the parameter.

B. *By Mr. R. J. Bartlett.*

From the point of view illustrated in § 7, the setting of the Sone scale would seem to be as follows :

' Measurements ' have been sought because of the existence of a factor in hearing experience commonly referred to as the loudness of the noise. This loudness is sensed as quantitative and can be differentiated from qualitative differences by which the nature of the source of the noise is differentiated. We thus reach the idea of quantity (or amount, or intensity, or value) of noise.

To facilitate comparison of this quantitative factor in various noises we need a scale, and such a scale can be built up by an additive process made possible by the fact that we have two ears and the loudness of noise from a given source appears to be halved when we close one ear.

If we obtain two sounds such that the one (A) heard monaurally is sensed as of identical loudness with the other (B) heard binaurally, then, on the assumption that the effects of the stimulation of the two ears are truly additive so far as experience of loudness of noise is concerned, the noise B will be half as loud (or great or intense) as noise A, and it becomes possible to build up a series of sources of sound the noises from which constitute a scale by which loudness may be measured. A suitable unit may then be agreed upon and named the ' Sone.'

The task outlined is a purely empirical one and is independent of ability or lack of ability to measure the energy content of the sound disturbance that is the external ' cause ' of the hearing experience. If, however, that energy content can be measured, the relation of these ' physical ' measurements to the already determined loudness measurements becomes of interest and will probably be of assistance in the construction of loudness scales of greater accuracy, but this relation to the measurement of the physical basis of the stimulus is of secondary interest and importance in the solution of the original task—that of measuring the loudness of a noise.

Further, the additive property of binaural hearing is not essential to the argument. A scale can equally well be built up by the use of an e.a.i. or j.p.d. method in which the subject passes judgments on the loudness of various sounds. As a matter of fact it is the close agreement between the results obtained by these latter methods and those given by the monaural-binaural method that justifies the acceptance of the additive property of binaural hearing as a fact.

C. *By Dr. N. R. Campbell and Dr. J. O. Irwin.*

From the point of view of § 8, if the ' Sone scale ' were based wholly on the monaural-binaural method, it would be a simple example of fundamental measurement (see Appendix II A).

We have a group of sources of sound. We find that we can assign numerals $a, b, c, \ldots$ to them so that the source represented by a heard by one ear only is as loud as the source b heard by one ear and source c by the other, if, and only if, the proposition $a = b + c$ is true of those numerals. Then we have measured, in the fullest sense and without dependence on any other magnitude, some property of the sources, which is not their intensity, and which is psychological and not physical (see Appendix IV, B). Moreover the order of the numerals is the same as the order of the sources heard always binaurally ; the property is therefore appropriately termed loudness.

We can now seek a numerical law between this property, loudness, and any other, e.g. intensity. Fig. 43 represents such numerical laws, one for each frequency, having most of the properties characteristic of the numerical laws of physics. The squares in Fig. 41 are merely another way of expressing the same numerical law.

Having measured loudness, we can inquire whether, when observers *guess* by direct inspection that a is half or a tenth as loud as b, they are usually right. For since, by measuring loudness, we have given to ' a half ' or ' a tenth ' a definite

meaning based on facts, a guess is right only if it is consistent with that meaning. The answer apparently is that they are right in respect of a half, but not in respect of a tenth (see Fig. 41). There is nothing very startling here. For exactly the same thing happens with length. Nearly everyone can 'estimate' half a scale division without regular error, but 'personal equation' enters strongly in estimating one-tenth or nine-tenths. This comparison of guesses with measurement is possible only because loudness has been measured independently of guesses; it does not give rise to or affect measurement. If what people estimated as a half turned out to be consistently less than a half, no physicist would propose to abandon measurement based on addition for measurement by guessing. Thus guessing halves in respect of weight and brightness is consistently wrong; but nobody proposes on that ground to abandon the use of balances and photometers. Nor does the use of those instruments prevent psychologists from inquiring how far, or why, guesses of weight or brightness are wrong, that is to say, inconsistent with physical measurement.

If the Sone scale is not based on addition by the monaural-binaural method and is based solely on guesses, then the position is very different.

Fig. 41 (open figures) still represents definite facts, namely that persons, told to choose B so that it is half as loud as A, do so consistently. But in deriving Fig. 43 from Fig. 41, it is assumed that B is to be represented by $\frac{1}{2}a$ if A is represented by a. This assumption is not justified by the facts.

For (*a*) the very meaning of a half implies the facts of addition on which the measurement of number, weight, length, etc., depends. If the observer were not familiar with such measurement, he would not use the word. He is not entitled to use the word unless the facts from which it derives its meaning exist in the sphere of discourse. But, if the monaural-binaural method is rejected, there is no evidence that the facts exist in this sphere.

(*b*) If it turned out that, having drawn Fig. 43 on the basis of guesses of a half, it represented equally well guesses of a third or a tenth, then there would be some justification for the assumption. But it does *not*. As the solid figures of Fig. 41 show, x sone will *not* be estimated as a tenth of $10x$ sone. Again if it turned out that an observer asked to choose a sound intermediate between x sones and y sones always selected some mean of x and y, say $(x+y)/2$ sone or $\sqrt{xy}$ sone, then there would be some, but not complete, justification. But that is definitely not so.

Accordingly the only effect of introducing the assumption by which (and by which only) Fig. 43 can be deduced from Fig. 41, is to produce a statement whose implications, other than those of Fig. 41 (open figures), are false. What, then, is the advantage of Fig. 43? Why do not psychologists accept the natural and obvious conclusion that subjective measurements of loudness in numerical terms (like those of length or weight or brightness) are mutually inconsistent and cannot be the basis of measurement?

The answer is apparently this. If they assume that Fig. 43 describes a relation between two magnitudes, measurable independently of each other, they can describe very simply certain facts that otherwise require a very complicated description. At certain stages in the history of physics and chemistry the same defence could have been, and was, offered for the use of the terms phlogiston, caloric, and æther, although it had already been shown that those terms had false implications. It is submitted that, in this matter, the young science of psychology might learn from the experience of its elders; it never pays in the long run to attempt to use error as a means to truth.

D. *By Mr. K. J. W. Craik and Prof. A. Ferguson.*

The first observation we would make is that we do not insist that one sensation may be expressed as so many times greater than another sensation. The sensation of sound has many aspects—loudness, pitch, volume, quality—and it is on one of

these aspects of sensation that we concentrate. In this instance *loudness* has been chosen.

The term loudness in what follows is always used with reference to the subjective aspect of the sensation.

It is admitted that loudness has magnitude in the sense that we can speak of two equal loudnesses, of one loudness being greater than another, and so on.

Further, it is admitted that, *without any direct reference to physical measurements of intensity*, different observers, A, B, C . . . may take an interval *a–e*, bisect it at a point *c*, and agree on the point *c*. Furthermore they may bisect *a–c* at *b* and *c–e* at *d*, agreeing on these points. A further bisection of the interval *b–d* should yield the same point *c*, and though the experiments of Gage dispute this, it has been shown by other observers that consistency is obtainable, provided the interval is not too large. Such *equal appearing intervals* may be obtained with other aspects of sound sensation, and with aspects of other sensations, and these equal appearing intervals are connected by a functional relation with the physical stimuli which produce the aspect of the sensation under consideration. The amount of such evidence is impressive, is continually increasing, and represents a psychological fact of high importance.

There is obviously something quantitative in these observations and it is difficult to deny the term *measurement* to them.

It seems reasonable to associate the numbers 1, 2, 3, . . . rather than such a series as 1, 3, 9, 27, . . . with the terms of these intervals in view of the fact that they are equal appearing, and we do not think that such a process of association is based on a false analogy with the putting of equal lengths end to end.

This may be further emphasised by the fact that a completely different method of approach, which avoids the possibility of such a bias, yields similar results. A tone heard by one ear appears subjectively half as loud as the same tone heard by both ears. The observer, therefore, adjusts the intensity of a tone heard by one ear until it appears to be of equal loudness with a given tone heard by both ears.

Suppose then we take an arbitrary intensity (40 db. above threshold) and assign to it the number 1. This so-called unit has been named a *sone*. A tone which sounds half as loud (as determined by the process just mentioned) is assigned the number of ½, a tone which sounds twice as loud receives the number 2, and so on. We can then plot a curve, for a given frequency, say 1,000 c.p.s., connecting physical intensities in db. above threshold with loudness in sones, and such a curve is, within the limits of experimental error, the same for all (normal) observers.

Such experiments have an obviously quantitative side. They represent important psychological facts, which have applications outside the laboratory. It is, of course, possible to define the term *measurement* in such a way as to preclude the application of the term to these experiments, but, in view of their number and importance, it seems advisable either to widen the definition of measurement in such a way as to include them, or to find an alternative term (? estimate) which shall emphasise their quantitative aspect without conflicting with the physical use of the term measurement.

E. *By Dr. L. F. Richardson, F.R.S.*

Experimental researches have shown that there is not a unique scale of loudness. There are many scales, each correct in its own way, but suited to different purposes. The fact that the physical scale of micro-watts–cm.$^{-2}$ is the same for all stationary observers is a merit for physical purposes ; and demerit for psychological purposes, because observers are obviously not all alike, some being in various degrees deaf. For psychology, introspective reports are prime evidence. They are not to be lightly brushed aside because they disagree with physical measurement. Thus, when we are studying psycho-physics, we ought not to say that ‘ Guessing halves in

respect of weight and brightness is consistently wrong.' The proper conclusion is 'consistently different from fundamental measurement in physics.' No physicist proposes on that ground to abandon the use of balances and photometers ; but, on the contrary, artists prefer not to use photometers.

Stevens and Davis describe several purely psychological scales of loudness for normal observers, namely, (α) intuitive ratios, (β) monaural-binaural equation, (γ) Sone scale, being a deduction from (α) and (β), (δ) bisection, (ϵ) just perceptible increments. The empirical fact that (α) agrees with (β) is of much interest. But it is best left as empiricism and not canonised as dogma. Stevens and Davis also show that (α) and (β) differ from (δ) and (ϵ).

There are those who say 'that the very meaning of a half implies the facts of addition on which the measurement of number, weight, length, etc., depend.' But that is an unproved assertion. For indeed the bisection of seen length can be performed by some people with such intuitive ease as to raise the question whether intuitive ratios may not be more primitive in the individual and in the history of the race than numerals or than addition. 11.6.39

Appendix II.

On Measurement.

A. *By Dr. N. R. Campbell : Notes on Physical Measurement.*

Measurement in its widest sense may be defined as the assignment of numerals to things so as to represent facts or conventions about them.

Numerals have by convention a definite order. If any other group of things has a definite order (so that any member of the group is equal to, greater than, or less than any other), numerals can be assigned so as to represent the fact of this order. But, if this is all, the assignment is not unique ; the same order can be represented by 1, 2, 3, 4, . . ., by 1, 4, 9, 16, . . ., or by 3, 8, 10, 17. . . .

In physical measurement the further condition (condition A) is imposed that the assignment must be unique to this extent, that, when a numeral has been assigned to one member of the group, the numeral to be assigned to any other member is or can be determined by facts within a limited range of 'experimental error,' arising from the nature of the facts that determine the assignment.

Only one way of fulfilling this condition has ever been discovered : in it use is made of the primary function of numerals to represent number, a property of all groups. The rule is laid down that the numeral to be assigned to any thing X in respect of any property is that which represents the number of standard things or 'units,' all equal in respect of the property, that have to be combined together in order to produce a thing equal to X in respect of the property.

The only properties measurable *directly* by means of this rule are those (roughly termed quantities) which are additive—that is to say, which are such that, given two things A and B having the property, it is possible to produce by a precisely determined operation (combination) a thing C which is greater in respect of the property than either A or B. Typical additive properties with their operations of combination are :

Length—placing end to end in a straight line.
Mass—connecting so as to form a single rigid body.
Electrical resistance—connecting in series.

Non-additive properties (roughly termed qualities) are measured by an *indirect* process, of which the simplest form is this. To each thing to be measured is assigned by the direct process two numerals, x, y, representing it in respect of two additive properties. The fact is established that the numerals representing some single-valued function, $f(x, y)$, have the same order as the non-additive property to be

measured. The numeral $f(x,y)$ is then assigned to represent the property. Examples of non-additive properties, with the additive properties of which they are thus functions, are :

Density—mass/volume.
Area of an ellipse—(length of major axis) $\times$ (length of minor axis).

The number of non-additive properties recognised in physics greatly exceeds that of additive, and there are many variants of the indirect process. It is unnecessary for the present purpose to distinguish them ; the important fact is that they all rest on the direct process and require the establishment by experiment of a law relating directly measured properties.

These simple principles are apt to be obscured by complexities that arise in any old and highly organised study. They are not likely to arise in any young study. A few of them will be pointed out.

The same property may be measurable both directly and indirectly from other properties ; electrical resistance and volume are examples.

Properties that are essentially different may be closely related by theory, and therefore called by the same name. Thus the mass of terrestrial bodies is measured directly. The mass of a star or of an atom must be measured indirectly ; the connection between the three properties is theoretical, because it would vanish if certain theories were rejected.

True measurement is relegated nowadays to instrument makers and standardising laboratories, who make standards or calibrated instruments which permit other things to be measured by mere judgment of equality. The nature of a standard or calibrated instrument does not indicate whether the underlying measurement is direct or indirect. Accordingly, since most physicists never make a direct measurement in the whole course of their experience, the distinction between direct and indirect measurement is apt to be forgotten.

The value to be assigned within the limits of experimental error is often set by mere convention. When the error is (as usual) much less in comparing nearly equal properties than in those very different several different 'units' may coexist. Thus the 'unit' for the mass of terrestrial bodies is the standard kilogramme, for the mass of stars it is the sun, for the mass of atoms it is O^{16} ; but the relation between these units is known within a range of error, arising from the facts on which the three measurements depend.

Since all measurement requires the establishment of facts (either the fact of additivity or the fact of a law between previously measured properties), every branch of physics is apt to go through a stage in which a tentative process of measurement is proposed, but is not yet fully established. The existence of such tentative processes is not evidence that, having decided that we want to measure something, we can proceed at once to do so ; it is evidence to the contrary.

During the discussions of the Committee it was suggested that the international scale of temperature affords evidence that physicists accept as measurement processes that do not conform to Condition A, and that therefore (this implication appears dubious) anyone might call physical measurement any process of assigning numerals, however arbitrary. It is therefore desirable to say something about temperature.

Within a certain range, temperature can be measured by the simple indirect process described above, in virtue of Boyle's Law, $pv =$ constant. The order of this constant is the order of temperature defined as a property such that, if the temperature of A is greater than that of B, A in contact with B will become of lower and B of higher temperature. If, then, a value of the constant were assigned to one body, the value to be assigned to any other within the range would be determinate.

But now two complications enter. For historical reasons it is desired to assign prescribed values, 0 and 100, to two bodies. Suppose that, having established a

direct process of measuring length and having assigned the value 1 to the standard metre, we found that the numerals to be assigned to most other bodies were inconveniently large. We might, by a mere convention, decide that we would subtract some particular numeral, say 100, from all the numerals thus assigned. That would not alter the fact that we *could* still measure length by assigning a single numeral. It would still not be altered if we said that we would subtract, not a predetermined numeral, but a numeral to be determined by experiment such that, when the standard metre has the value 100, the standard yard has the value 0. That is the whole matter in respect of the fixed points 0° C. and 100° C. ; we deliberately sacrifice the advantages of a single arbitrarily assigned numeral in order to maintain historical continuity ; but the measurement is still physical measurement, because we could, if we pleased, determine all numerals by making a single arbitrary assignment.

The other complication enters because we have theoretical reason to believe that the property measured thus by Boyle's Law is significant far outside the range over which Boyle's Law is true as an experimental fact. The position then is exactly the same as that in respect of the mass of atoms and stars. Two possibilities now arise. One is that we can find true processes of measuring this property, by relations other than Boyle's Law, over the whole range where it is supposed to exist at all, but that the experimental error of these processes is undesirably large. Then (just as with the mass of atoms) we may assign by convention a whole series of temperatures throughout the entire range, taking care that they always lie within the range of experimental error.

If this is the fact (and it was certainly believed to be the fact by the convention which set up the 7 (or 9) ' fixed points ' of the international scale and the method of interpolating between them), the statement that (e.g.) the melting point of sulphur is 444·6° means this : We have processes of measuring temperature over the whole range which determine that the melting point of sulphur must lie between (say) 444° and 445°, the extent of this range being determined by the nature of those processes. But in the neighbourhood of that temperature, we can compare temperatures within much narrower limits. Accordingly we assign an arbitrary convention that that temperature is to be taken to be 444·6°. If that is all, temperature is not different from many other magnitudes concerning which similar conventions are made.

It is to be observed that, on this view, the question whether the conventional value is right may arise. If the range of experimental error in the processes of measurement could be sufficiently decreased, the conventional value might be found to lie outside the decreased range, and would then be definitely wrong.

The other possibility is that we cannot find any processes at all for measuring the theoretical property (thermodynamical temperature) that we desire to measure. Some physicists hold that this is the actual fact, and that all methods that profess to measure thermodynamical temperature rest in part on purely arbitrary conventions that have no factual basis. If this is so, the international scale is not measurement at all ; we cannot measure temperature outside the range of Boyle's Law (and perhaps a few other laws of limited range) ; and that is the end of the matter.

But the possibility of such an attitude is proof that physicists have very definite criteria of measurement, and that measurement is possible only in virtue of facts that have to be proved and not assumed. 27.6.39

B. *By Mr. T. Smith, F.R.S. : Description of Estimated Magnitudes.*

The term ' apparent distance ' has been used in optics for more than two centuries. It denotes the distance a man would be judged to be from his height and the angle his image subtends at an observer's eye. It may be useful to extend the application of the word to distinguish between true and estimated quantities such as weight,

etc. A length of 1 foot would then signify a value obtained by physical measurement, and an apparent length of 1 foot an estimate made under conditions to be described. 3.7.39

Appendix III.

In defence of the Measurability of Sensation Intensity.

A. *By Mr. K. J. W. Craik.*

The Committee seems to me to have been facing two main questions :

(*a*) Is sensation intensity measurable ?

(*b*) Why should anyone want to make out that sensation intensity is measurable, and why should anyone want to measure it ?

The answer to the first of these questions must be sought by finding a definition of measurement which fits its use in other sciences, and then asking whether the facts obtained by psycho-physical experiments entitle the estimation of sensation magnitudes to be subsumed under this definition. It is important not to base the definition of measurement only on the most stringent instances, such as length ; for ' measurement ' is applied also to scales of temperature, density, time, etc., which fail to fulfil one or other of the conditions which are fulfilled by length. Thus, to insist that a quantity is measurable only if the operation of adding together two numerical quantities predicts the result of combining such quantities of the given physical magnitude, would rule out the temperature scale quite as much as a sensation scale. Again, subjective estimation of sensory intervals may break down when the intervals are large. But in the same way measurement of space according to the rules of Euclidean Geometry may break down when applied to stellar distances ; but one does not assert, for this reason, that measurement extending over small distances, and performed by people who are ignorant of the failure for large distances, is therefore not measurement at all.

The same danger—the definition of measurement in terms of the cases which fulfil the most stringent requirements—seems to be at the root of the complaint that a sensation scale might lead the ' ordinary man ' to false conclusions. So might a logarithmic scale of weight, or the temperature scale. If the ordinary man's notion of measurement is based on length alone, it is probably too rigid even for physics.

The second question is of a different nature ; it seems to have been in the minds of those who have insisted that the results of psycho-physical experiments could be fully expressed in terms of stimulus intensities alone. It is more difficult to answer, for one certainly cannot point to any numerical data which can only be stated in terms of a scale of sensation magnitudes. But surely the same can be said in physics ; it is possible to refuse to do more than state results in terms of the methods by which they were obtained ; that is what Operationalism tries to do. On the other hand it is possible to unify results by introducing new quantitative concepts, such as electro-magnetic radiation of different frequencies, gravitational fields varying as the inverse square of the distance, and so forth. Such quantitative concepts generally make prediction easier, and, further, I see no reason to deny that they are in themselves explanatory concepts, of the kind which science seeks. If, then, a sensation scale can help to co-ordinate the data on masking in sound, or on the brightness of lights viewed with eyes in equal or different conditions of adaptation, I feel much in favour of giving such measurement a chance, rather than denying it all opportunity to see what it can do. 16.6.39

B. *By Mr. R. J. Bartlett.*

The Committee are on safe ground in § 7 of the Report in agreeing that the arguments of Fechner are fallacious : that has been accepted by psychologists from

an early date. They are also wise in their discrimination between the truth of 'conclusions' and the truth of methods of 'proof.' It would, however, seem doubtful whether they are justified in the interpolated statement 'that no numerical relation between the value of the stimulus and the intensity of the sensation can be deduced logically from the equation $\delta I = f(I)$.' The δI is not *any* difference of stimulus values: it has a unique value established by psycho-physical methods on the basis of just appreciable differences in the intensities of the sensations awakened by a stimulus of fixed physical value and by a unique value of a similar varying stimulus. Sensation intensity, not stimulus 'intensity,' is the deciding factor. Weber's Law is meaningless apart from its reference to sensation intensity.

Fechner's task was to give acceptable mathematical shape to this truth. He was faced with two series: one, a stimulus series, relatively permanent in space and time; the other, a sensation series, each member of which has a fleeting temporary existence. He could have taken any chance series of sensations and shown that the sensations could be ranked in order and that the corresponding stimuli proved to be ranked in order according to their physical values. On the strength of this he might have suggested that the physical values were suitable measures of the sensation intensities, and, in all probability, physicists of his day would have raised no objection. Instead, he paid closer attention to the possibilities of the sensation series. Instead of dealing with any haphazard series he proceeded to consider a series of sensation intensities each of which was just appreciably different from its next neighbours. The physical measures of the members of the corresponding stimulus series form a reasonably close approximation to a geometric progression. It is then an easy task to demonstrate that the physical value of the stimulus corresponding to the nth term of the sensation series can be expressed in the form Ka^n, where K and a are constants determinable by psycho-physical methods.

We can now determine the position of a sensation in an established order of sensations by reference to the corresponding stimulus value. But the numerical value of position is only a measure in the sense that it gives the number of steps between itself and a datum, and it is arguable that it would be well to be satisfied with that degree of measurement, i.e. measurement by enumeration of steps. If, however, by a reasonable convention we postulate equality in the value of the steps, we can establish a unit of sensation difference, and Fechner's Law follows: that sensation (in some reasonable sense) is proportional to the logarithm of the stimulus value. Fechner's arguments in support of the postulate break down because he assumes that a difference between sensations is itself a sensation. The steps are not *sensations*. There remains, however, the fact that the steps are the same, at least to the extent of each being 'just noticeable.' How to express the sameness in acceptable terms is the real difficulty, and, with nothing better in the field, it would seem reasonable to accept Delbœuf's contention that the sameness is equality of 'sense-distance' and that it is 'sense-distance' that is measurable and gives acceptable meaning to Fechner's Law. 27.6.39

Appendix IV.

In denial of the Measurability of Sensation Intensity.

A. *By Mr. J. Guild.*

I had the privilege of explaining at some length my views on the fundamental problem which the Committee has been examining in the Interim Report published last year,[2] so it is unnecessary for me to repeat the arguments given therein. I need

[2] *Are Sensation Intensities Measurable?* Statement III in Interim Report of Committee appointed to consider and report upon the possibility of Quantitative Estimates of Sensory Events, *Report of British Association for Advancement of Science*, 1938, p. 277.

only say that nothing which has been advanced in the subsequent deliberations of the Committee appears to me to call for any modification of the views I expressed in that statement, or to limit the generality of the conclusion that sensation intensities are not measurable in any sense of the term. I submit that any law purporting to express a quantitative relation between sensation intensity and stimulus intensity is not merely false but is in fact meaningless unless and until a meaning can be given to the concept of addition as applied to sensation. No such meaning has ever been defined. When we say that one length is twice another or one mass is twice another we know what is meant : we know that certain practical operations have been defined for the addition of lengths or masses, and it is in terms of these operations, and in no other terms whatever, that we are able to interpret a numerical relation between lengths or masses. But if we say that one sensation intensity is twice another nobody knows what the statement, if true, would imply. I do not know of anyone among the psychologists I have met or whose works I have read who would claim to know. In fact, I have always understood it to be an accepted tenet of orthodox psychology that every sensation is, as regards its intensity, an indivisible thing which cannot be analysed into smaller sensations piled on top of one another. Any statement of a numerical ratio between two samples of a magnitude implies the possibility of this kind of analysis which psychologists are agreed is inapplicable to sensation intensity. Without this possibility (of analysis into parts combined by a defined operation of addition) we cannot assign a meaning to ratio, and when we talk about relative values of sensation intensities we are merely using groupings of words which seem to make sense only because we are familiar with their use in connection with well-defined physical magnitudes, whereas when applied to sensation intensities they make sheer nonsense. If those who insist on the view that quantitative laws must exist between stimulus and sensation intensities were less preoccupied with the discussion of what particular laws are true and would stop to inquire what any of the proposed laws, if true, would *mean*, they would find that no meaning in any way analogous to the meaning of a quantitative law as understood in physics and mathematics is discoverable. I believe (subject to correction) that all members of the Committee would admit this, but there are some who claim that the physicist places too narrow restrictions on the term ' measurement,' and that those working with other material (psychological material, for example) are not bound by these restrictions, and are entitled to regard as measurement any process of associating numbers with things which is found to be repeatable under prescribed circumstances whether or not this process has anything in common with physical measurement. This merely begs the whole question at issue. There is no doubt that the desire of psychologists to be able to apply the processes and concepts of measurement to the field of sensory experience is due to the success of such processes in physics and geometry, and that their aim is to introduce the same kind of definiteness into descriptions of sensory behaviour that quantitative laws give to descriptions of physical phenomena. I am sure that when they propose a quantitative law they intend its quantitative significance to be of the same kind as that of any other quantitative law. What some of them (not all) appear to be unable or unwilling to do is to realise that they cannot obtain this significance in relations involving numbers derived from processes of types differing fundamentally from those which form the basis of all physical measurements. To insist on calling these other processes measurement adds nothing to their actual significance but merely debases the coinage of verbal intercourse. Measurement is not a term with some mysterious inherent meaning, part of which may have been overlooked by physicists and may be in course of discovery by psychologists. It is merely a word conventionally employed to denote certain ideas. To use it to denote other ideas does not broaden its meaning but destroys it : we cease to know what is to be understood by the term when we encounter it ; our pockets have been picked of a useful coin. I pointed out in the

Interim Report that there are many psychological relations expressible on a truly quantitative basis, involving sensory magnitudes measurable in the accepted sense of this term. These are all 'B' magnitudes (in Dr. Norman Campbell's well-known classification) and are definable as ratios of two or more stimulus quantities related in a manner determined by some sensory property. Sensation intensity is not a thing of this kind. It is not definable in terms of stimulus quantities. Any concept of a numerical relation between two unequal sensation intensities must be based on an analysis of sensation intensity into parts from which it can be resynthetised by a defined operation of addition. This has never been done. Until it is done it is meaningless to speak of numerical relations between sensation intensities.

We are entitled to ask those who regard this conclusion as merely an unproved assertion, and who hold that in some mysterious way it is possible to intuit numerical relations, to provide some statement of the meaning of the ratios they claim to identify by this means. Presumably when they assert, for example, that one loudness is twice another, the statement is supposed to be meaningful. What is this meaning ? Before we can say we are aware of some fact, no matter by what means we claim to become aware of it, it is necessary to be able to say what the fact is. It is not sufficient to say : the fact which we intuit *is* simply that one loudness is twice the other and that is all that can be said about it. We must be able to say what relations between sensation intensities and numbers are implied by the assertion that the numerical ratio 2 : 1 is appropriately associated with the directly experienced relation between the loudnesses. If we deny the applicability of the kind of relation (based on a practical criterion of equality and operation of addition) employed in physical measurement, we must substitute some other if our statements are to mean anything. What other is in the minds of the exponents of intuitive measurement ? I venture to suggest there is none. They claim that the concept of measurement must be extended, but in fact they do nothing to extend it ; they offer no suggestion of any basis on which to build relations between numbers and things that are not numbers which will serve as an alternative to the physicist's basis. They seem to think that no defined relations are necessary and that the words *twice* or *half*, etc., have a meaning in whatever context one chooses to use them.

Almost at the end of the Committee's deliberations our attention was directed to a type of experiment which some psychologists think may provide an operation of addition for at least one kind of sensation intensity—loudness. This is the monaural-binaural experiment described in another appendix to this report. It must be observed in passing that the claim that we may assume the total sensation in binaural hearing to be the simple sum of component sensations due to the stimulation of the respective ears is at variance with the generally accepted psychological principle, already referred to, that sensation intensities, from their nature, are not susceptible of analysis or synthesis, and we would expect some cogent reasons for abandoning that principle to be advanced before any assumption of the kind here involved were made. In any case an *assumption* will not do. It merely leaves us with the same question as before, namely, what is the nature of the facts which are assumed ? We must, obviously, have an idea of what is implied by the addition of sensations before we can *assume* that addition is taking place in this experiment. If addition has no meaning, neither has the assumption that it is happening. The two constituent sensations whose additivity is here said to be assumed have no separate identity at any stage of the proceedings. Their separability and additivity is purely conceptual and has no factual significance.[3] The process employed in the

[3] It is easy to make verbal formulations of meaningless analyses of this kind. It is easy to *say*, for example, that the taste of sugar is three times one-third of the taste of sugar. This sort of thing sounds all right but means nothing whatever, because there are no operations or criteria which give meaning to the concept of subdivision of a taste. The statement does not itself provide a meaning for the concept involved. A definition of the meaning of the terms used must come first, before any statement employing the terms can make sense.

monaural-binaural experiment, and the assumptions made, have nothing in common with the processes and postulates (not assumptions) employed in constructing a standard scale for any magnitude, as examination in the light of the principles outlined in my previous statement will reveal. That numbers obtained in the monaural-binaural experiment are related to stimulus intensities in a similar manner to those obtained by some other processes does not prove or confirm that any of the processes constitutes measurement of sensation intensities. It merely indicates that some common psychological or physiological factor may be entering into all the various experiments. The fact is clearly of importance, but its significance is not likely to be discovered so long as experimenters in these fields remain preoccupied with the idea that they are measuring sensation intensities. 20.6.39

B. *By Dr. N. R. Campbell : Physics and Psychology.*

Physics is the discovery and study of those relations between sense-perceptions concerning which universal agreement can be obtained. Psychology is interested in all sense-perceptions, however individual they may be. Psycho-physics occupies an intermediate position ; it uses physical conceptions, based on common relations, to describe relations that are not common. Thus, in the description of a j.p.d. experiment, the values of the stimuli between which the subject is asked to distinguish are physical conceptions ; but the relation that the subject establishes between them is not a universal relation, because it can have no meaning for one who lacks the particular sense concerned.

No general objection can be taken to this psycho-physical procedure. For, though logical contradiction *might* arise from the mingling in the same proposition of conceptions that derive their significance from the universality of certain relations with other conceptions that derive their significance from individual differences in respect of other relations, such contradiction is not inevitable. Accordingly, with the rest of the Committee, I see no reason why, if the relations in which psycho-physics is interested prove to have a sufficient generality, they should not be regarded as proper subject-matter for laws.

But the position is very different when it is assumed that psycho-physical propositions have the same character and significance as purely physical propositions. Thus certain assumptions that physicists habitually make, when they are dealing with their proper subject-matter, are justified only by their experience that these assumptions turn out to be true in respect of that subject-matter. Such assumptions are that any ordered property will prove to be measurable, that a numerical law can always be discovered between two measurable properties invariably associated, and that, if this law is mathematically simple, it will prove to be general and explicable by a theory of the physical type. All the experience of physicists shows that, though these assumptions are true when great care is taken that the subject-matter has been carefully freed from all relations that are not universal, this precaution is absolutely necessary, and that the assumptions are untrue if it is relaxed to the smallest degree. Physics can use its characteristic procedures only in so far as it confines itself to relations (especially those of simultaneity and contiguity) that are truly universal.

Some psycho-physicists ignore all this. Having found that individual sensations have an order, they assume that they are measurable. Having travestied physical measurement in order to justify that assumption, they assume that their sensation intensities will be related to stimuli by a numerical law. And having thus established laws which, if they mean anything, are certainly false, they hope by the study of them to arrive at far-reaching theories.

I suggest that there are only two rational alternatives. One is to declare that the distinction between common and not-common relations, on which physics is based, is irrelevant to psychology, to reject all physical rules and procedures, and to

build up a completely new science with rules and procedures of its own. The other is to use physical conceptions, but only in a manner consistent with their significance, as in the description of a j.p.d. experiment. If it is said that no progress can be made subject to this limitation, the example of colour study will prove the statement to be false. We probably know more about the colour sense than about any other special sense; and the knowledge has been obtained by the use, and without the abuse, of physical conceptions. 26.6.39

C. *By Mr. T. Smith.*

I am in substantial agreement with the views already expressed that measurement must conform to the principles followed in physics.

I think it is not disputed that sensations are not measurable in the sense in which the term is used by physicists. I would agree that the measurement of sensations, if it were possible, might prove valuable. Many attempts have been made to devise methods of assigning values which could be logically defended as measures of sensations. All of these attempts have failed, and in the present state of knowledge there are no grounds for expecting success.

The fundamental objections urged elsewhere apart, it is noteworthy that in the course of attempts to set up scales of sensations assumptions are made which have the effect of begging the whole question at issue. Sometimes the assumptions involve propositions known to be false, and the arguments employed can often be used equally well to justify scales differing markedly from the one arbitrarily chosen. The conclusion to be drawn is that though we can order a series of sensations, and so assign numerals to them on any one of many systems, we have no justification for regarding the numbers, or any function of them, as measures of the sensations.

Consider by way of example a j.p.d. series and the derivation from it of Fechner's Law as suggested in Appendix III, B. It is tacitly assumed that there is a one-one relation between stimulus and sensation valid for all the observations; but this is certainly not true for different states of adaptation of the sense organ. In the successive steps the state of adaptation changes, for the stimuli are continuously increasing (or continuously decreasing). It follows that the 'sense-distance' (assuming for the sake of argument that this is a something capable of quantitative expression) between the end sensations is not equal to the sum of the elements from which it is supposed to be built up, the magnitude of the discrepancy being unknown. As a special case—perhaps an extreme example of the cases possible—we may suppose all the lower stimuli of a series of steps to give rise to the same sensation, and all the higher stimuli to another constant sensation. The theory proposed would then lead us to assign a whole series of different measurements to each of the two sensations experienced. We should, in this case, expect Weber's Law to be true, but Fechner's would be false. In any event it would be astonishing if the conversion of ordinal numbers in this way, to represent values, were found ultimately to lead to correct conclusions.

Although Fechner's error, as mentioned in § 7, does not necessarily imply that his conclusion was false, it should be realised that objections of a different character from those mentioned here can be urged against the suggestion that L should be regarded as a true measure of sensation intensity. 3.7.39

Appendix V.

On Mathematical Transformations and Sensation.

By Dr. R. A. Houstoun.

In § 5 of the report it is stated that when a relation $\delta I = f(I)$ has been established, it is always possible to calculate the integral $L = \int du/f(u)$, but that such trans-

formations neither add to nor subtract from the *facts* expressed by the relation between δI and I. I take exception to this statement. I think that such transformations may suggest analogies with other results in physics and thus throw light on the nature of the processes involved in sensation.

For example, it is known that Weber's Law on the constancy of $\delta I/I$ does not hold for observations on the brightness of surfaces throughout the entire range. I have found in this case (cf. my book *Vision and Colour Vision*) that $I/\delta I$ is a probability curve when expressed in terms of log I, though my results have been questioned. It is not necessary, however, for the validity of my objection that my conclusions from the data should be correct.

If we *assume* that

$$\frac{I}{\delta I} = e^{-(\log I)^2/2\sigma^2}$$

where σ is a constant, and write

$$L = \int_{-\infty}^{\log I} e^{-(\log I)^2/2\sigma^2} \, d(\log I)$$

then

$$\delta L = e^{-(\log I)^2/2\sigma^2} \, \delta(\log I)$$

which becomes unity, if δI is the j.p.d. Thus the increase in L between two degrees of stimulus is equal to the number of steps of j.p.d. in the range. But the integral is proportional to the fraction of a homogeneous population which varies with respect to log I and has a value of log I below a certain limit. This suggests that the sensation of brightness is due to a number of receptors which have different thresholds and that it is directly proportional to the number of these receptors which are in action.

The point I wish to stress here is that by mathematically transforming results we see them from a new angle and that the new standpoint sometimes reveals relations existing between them. 25.5.39

SECTION C (GEOLOGY)

PHOTOGRAPHS OF GEOLOGICAL INTEREST

TWENTY-NINTH REPORT of the COMMITTEE (Prof. E. J. Garwood, F.R.S., Chairman ; Prof. S. H. Reynolds, Secretary ; Mr. H. Ashley, Mr. G. Macdonald Davies, Mr. J. F. Jackson, Dr. A. G. MacGregor, Dr. F. J. North, Dr. A. Raistrick, Mr. J. Ranson, Prof. W. W. Watts, F.R.S.).

The membership of the Committee remains as it was at the Nottingham meeting in 1937.

In the present report 236 photographs are listed bringing the number in the collection to 9,102. The collection continues to receive sets from former contributors, the present series including 13 more Cornish subjects from Mr. E. H. Davison, 9 from East Anglia and 17 from Antrim from Mr. H. Ashley, and 6 from Sutherland from Mr. A. G. Stenhouse. In addition to further subjects from the Bristol district the Secretary contributes a small series from Ireland. New contributors include Prof. P. G. H. Boswell and his colleagues, Drs. A. C. Skerl and E. Spencer, who send 9 fine photographs from Denbigh. Dr. J. E. Wynfield Rhodes sends 6 from Caernarvon and 10 from Dumfries, the latter county being little represented in the collection.

There can be little doubt that the most important subjects included in the present list are those from Westmorland contributed by Mr. T. Hay. Some of these are of mountain scenery, others of glaciation, but the special importance of the series is that it includes illustrations of certain erosion phenomena, characteristic of mountain regions, and hitherto unrepresented in the collection, such as solifluction-weathering, slab- and block-weathering, stone stripes and frost action. Mr. Hay has also contributed certain excellent photographs of mountain scenery in Scotland taken by Mr. B. Redford.

GEOLOGICAL NEGATIVES.

Since the issue of the previous report the Committee has become the possessor of no fewer than 307 negatives taken by one of its members Mr. J. F. Jackson. Prints of the whole series had already been added to the collection. Of these, 230 illustrating the geology of the Isle of Wight were taken by Mr. Jackson in 1924 and 1925 when acting as scientific assistant to the late Mr. Frank Morey, F.L.S., and were presented by Miss C. Morey ; the remaining 67 illustrating the geology of parts of the coast of Devon and Dorset were presented by Mr. Jackson himself. This very fine series, all fully described, is the most important that has been acquired by the Committee with the exception of the Reader collection presented in 1925.

The following smaller sets have also been acquired recently :

(*a*) 130 negatives—62 ¼-plate and 68 ½-plate of various localities, presented by Mr. C. J. Watson ;

(*b*) 38 negatives illustrating the South of England, mainly Somerset, presented by Dr. F. J. Allen ; 33 of these are whole-plate, the remainder 5 × 4 ;

(*c*) 47 whole-plate negatives illustrating the coast near Penzance and Sidmouth, purchased from Mr. Harold Preston of Sidmouth ;

(*d*) about 40 negatives of the Bristol district, presented by Mr. J. W. Tutcher.

It is hoped that other sets may be acquired shortly.

It has unfortunately happened that very large numbers of geological negatives have been destroyed by executors, often from ignorance of their importance. The most regrettable case is that of the Jerome Harrison collection, numbering 380 negatives. Other sets destroyed are those of W. Goodchild (44), and Prof. G. A. J. Cole (30). Many hundred negatives in small sets have undoubtedly been destroyed. It would scarcely be incorrect to say that any good geological negatives of British subjects would be acceptable to the Committee.

The normal and most satisfactory course is for large collections of negatives to find a home eventually in the geological department of the nearest University or large Museum. Thus the Welch collection is now in the City Museum, Belfast ; the Bingley collection in the University of Leeds ; while the series taken by the Secretary is destined for the University of Bristol.

The housing of the property of the Committee is a difficult question. It consists of the following : (*a*) the collection of photographs mounted in about 100 albums ; (*b*) the card catalogue contained in a large case ; (*c*) the negatives alluded to above ; (*d*) two cupboards containing the spare copies of the successive reports and other printed matter ; (*e*) the negatives of the published series and the corresponding lantern-slide negatives ; (*f*) miscellaneous property of various kinds.

The series of albums has always, through the kindness of successive Directors, been kept in the library of H.M. Geological Survey. The collection has, however, almost outgrown the cupboard space provided for it, and this space would undoubtedly be acceptable for purposes of the library. The collection cannot be worked at without inconveniencing the library staff by occupying table-space.

With the exception of the albums all the Committee's property is at Bristol. Such a separation adds greatly to the difficulty in caring for the collection, but under

present circumstances is unavoidable. It was hoped that in the new Survey building it might be possible to assign a small room which could be used solely for the purposes of the collection.

The Secretary intended that the present report should be the last for which he was responsible, and that it should include a balance sheet and a general statement regarding the published series and the collection. He now proposes to carry on for one further period and to postpone the issue of the balance sheet and statement regarding the collection.

ENGLAND.

BUCKINGHAMSHIRE.—Photographed by J. H. PLEDGE, formerly of 115 Richmond Road, Dalston, N.E. ½.

8866.	30.	Dorton.	Railway cutting in Ampthill Clay.

CAMBRIDGESHIRE. Photographed by the late Mrs. T. MCKENNY HUGHES (before 1911). ¼.

8867.	—	Barrington.	Pit in mammaliferous gravel.

CORNWALL.—Photographed by E. H. DAVISON, B.Sc., School of Mines, Camborne, Cornwall. P.C.

8868.	20.	Widemouth Bay, near Bude.	Syncline in Culm Measures. 1938.
8869.	87.	Delabole Quarry.	Quarry in Devonian roofing slate. 1939.
8870.	58.	Roche Rock.	Mass of schorl rock. 1938.
8871.	25.	Tremore Quarry, near Withiel.	Dyke of granite porphyry. 1938.
8872.	40.	Quarry ½ mile N. of St. Teath fork on Wadebridge-Camelford Road.	Porphyry dyke in shale exposed along line of strike. 1939.
8873.	86.	Godrevy Cliff.	Blown sand cemented by carbonate of lime derived from shells. 1939.
8874.	88.	Godrevy Cliff.	Raised beach. 1939.
8875.	51*a*.	St. Michael's Mount, foreshore.	Vein of greisen with quartz vein in centre, in granite. 1938.
8876.	51*b*.	St. Michael's Mount, foreshore.	Veins of greisen with quartz veins in centre, in granite. 1938.
8877.	80.	Kiberick Cove, near Veryan.	Erratic of serpentine on beach. 1939.
8878.	85.	County Council Quarry, Goonhilly Down, Lizard.	Thrust-fault in tremolite serpentine. 1939.
8879.	37.	Quarry, Botallack Head, St. Just.	Fold in actinolite gneiss formed from epidiorite. 1939.
8880.	23.	Cape Cornwall, St. Just.	Promontory due to epidiorite sill. 1938.

DORSET.—Photographed by F. J. ALLEN, M.D. (Cantab.), Shepton Mallet (formerly of Mason College, Birmingham). 1896. 1/1.

8881.	—	Lyme Regis Bay.	
8882.	—	Lyme Regis.	Lias cliff.

Photographed by W. J. ARKELL, M.A., D.Sc., Hurstcote, Cumnor, Oxford. ¼.

8883.	—	Watton Cliff.	Fuller's Earth section.
8884.	—	Coast W. of Bat's Head, Lulworth.	Chalk cliffs.

Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1928. ¼.

8885.	28·2.	East Cliff, West Bay, Bridport.	Bridport sands.
8886.	28·5.	East Cliff, West Bay, Bridport.	Bridport sands with calcareous layers.

Durham.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1931. ¼.

8887.	31·130.	Trow Rocks.	Cellular breccia at base of Middle Magnesian Limestone.
8888.	31·104.	Fulwell.	Concretions.
8889.	31·89.	Copt Hill.	Quarry in Whin Sill.
8890.	31·106.	Claxheugh, by the Wear.	'Lower Limestone' resting on 'Yellow Sands.'

Gloucestershire.—Photographed by F. J. Allen, M.D. (Cantab.), Shepton Mallet (formerly of Mason College, Birmingham). 6 × 8.

8891.	—	Stonehouse Quarry.	Middle Lias section.

Photographed by W. J. Arkell, M.A., D.Sc., Hurstcote, Cumnor, near Oxford. ¼.

8892.	17.	Leckhampton, near Cheltenham.	'Escarpment' (artificial cliff) Inferior Oolite (Lower Freestone).
8893.	18.	Leckhampton, near Cheltenham.	'Devil's Chimney,' an artificial stack of Inferior Oolite.
8894.	19.	Leckhampton, near Cheltenham.	Inferior Oolite Series.

Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. ¼ unless otherwise stated.

8895.	01·39.	Leckhampton Hill, Cheltenham.	The Ragstones.
8896.	38·3.	Hobbs, May Hill.	Disturbed Wenlock Limestone.
8897.	99·45.	Avon Gorge, from Observatory Hill.	Shows the level surface of Durdham Down and Leigh Woods. ½.
8898.	18·46.	Avon Sect., N. end with Sea Walls.	Z-beds of Black Rock Quarry and K section (wooded) beyond. ½.
8899.	18·63.	Avon Sect. (rt. bank).	Great Quarry from Leigh Woods. ½.
8900.	35·7.	Avon Sect. (rt.) southern part from Leigh Woods.	Great Quarry to Bridge Valley Road. ½.
8901.	35·15.	Avon Sect., Great Quarry.	*Seminula*-pisolite.
8902.	12·57.	Avon Sect., Great Quarry.	*Seminula*-pisolite.
8903.	38·7.	Avon Sect. (rt.), D_1.	Shows several stages in the formation of pseudobreccia.
8904.	38·9.	Avon Sect. (rt.), D_1.	Shows several stages in the formation of pseudobreccia.
8905.	28·38.	Avon Sect. (rt.), D_1.	Wide band of pseudobreccia.
8906.	38·8.	Avon Sect. (rt.), D_1.	Irregular pseudobrecciation.
8907.	28·39.	Avon Sect. (rt.), D_1.	Regular band of pseudobreccia.
8908.	28·37.	Avon Sect. (rt.), D_1.	Unbrecciated block in band the rest of which is pseudobrecciated.
8909.	20·15.	Clifton Down, near Suspension Bridge.	Pisolite S_2.
8910.	20·10.	Avon Sect., Great Quarry.	*Spongiostroma* limestone. S_1.

8911.	12·58.	Avon Sect., Great Quarry.	Block of *Lithostrotion martini*. S_1.
8912.	20·21.	Avon Sect., riverside exposure of rt. bank.	Crinoidal limestone. Z_2.
8913.	20·18.	Clifton Down, near Suspension Bridge.	*Seminula*-band in S_2.
8914.	20·16.	Clifton Down, near Suspension Bridge.	Pisolite S_2.
8915.	99·30.	Clifton Down, near Suspension Bridge.	Infilling of Rhætic breccia left by quarrymen after removal of limestone.
8916.	06·155.	Shirehampton railway cutting.	O.R.S. section, rocks on left undisturbed.
8917.	06·156.	Shirehampton railway cutting.	O.R.S. section, rocks on left undisturbed.
8918.	18·73.	Avon Sect., block of 'Palate Bed,' (K_1).	Several teeth of *Psephodus minimus* showing.
8919.	18·77.	Avon Sect. (rt.), (K_2).	Slab of Bryozoal limestone.
8920.	01·63.	Sodbury cutting.	Trias with sharply folded Lower Lias faulted against D-beds. ½.
8921.	01·61.	Sodbury cutting.	Trias unconformable on D-beds. ½.
8922.	01·56.	Sodbury quarry.	Section of Upper S_2 and Lower D_1. ½.
8923.	19·25.	Sodbury quarry.	'Concretionary Beds.' S_2. ½.
8924.	36·1.	Sodbury Quarry, N.E. portion.	Overthrust faults in Carb. Lst. ½.
8925.	36·2.	Sodbury Quarry, N. and W. sides.	On W. side Trias conglom. rests on Carb. Lst. ½.
8926.	36·3.	Sodbury Quarry, general view from S.	On right Rhætic, on left Trias conglom. on Carb. Lst. ½.
8927.	36·4.	Sodbury Quarry, N.E. portion.	Rhætic resting on overthrust Carb. Lst. ½.
8928.	34·86.	Sodbury Quarry.	Rhætic resting on planed surface of Carb. Lst.
8929.	37·5.	Sodbury Quarry.	Carb. Lst. twice overthrust on Rhætic.
8930.	37·4.	Sodbury Quarry.	Carb. Lst. twice overthrust on Rhætic.
8931.	36·5.	Sodbury Quarry.	Trias conglom. resting on Carb. Lst. ½.
8932.	34·7.	Sodbury Quarry.	Rhætic resting on planed surface of Carb. Lst.
8933.	36·7.	Sodbury Quarry.	Rhætic on overthrust Carb. Lst.
8934.	34·88.	Sodbury Quarry.	Griked surface of Carb. Lst.
8935.	38·4.	Mitcheldean, Wilderness Quarry.	Old Red Sandstone section.
8936.	32·45.	Mitcheldean, Hazel Hill Quarry.	Opened along strike of Lower Lst. Shale.
8937.	18·84.	Garden Cliff, Westbury-on-Severn.	Block of Rhætic bone-bed. ½.

Photographed by the late J. E. LIVINGSTONE, The University, Bristol. ½.

8938.	—	Scully Grove, Mitcheldean.	Algal limestone, surface shown at right angles to bedding.

8939.	—	Scully Grove, Mitcheldean.	Weathered surface of bedding-plane of algal limestone.

Photographed by Sir T. Franklin Sibly, LL.D., The University, Reading. ½-pl. enlargement.

8940.	—	Scully Grove, Mitcheldean.	Whitehead Limestone section.

Photographed by ?.

8941.	—	Cementstone Quarry, Mitcheldean.	Lower Lst. Shale section.

Norfolk.—Photographed by A. T. Metcalfe, Southwell, Notts. 9½ × 7 (approx.).

8942.	L. 63.	Cromer, looking N.	Rapid erosion of the cliffs.
8943.	G. 13.	Between W. Runton and Sheringham.	Contorted glacial drift.
8944.	G. 15.	Between W. Runton and Sheringham.	Contorted glacial drift.
8945.	G. 17.	Between W. Runton and Sheringham.	Contorted glacial drift.
8946.	G. 16.	Between W. Runton and Sheringham.	Contorted glacial drift.
8947.	G. 18.	Cliff, E. end of Sheringham parade.	Contorted glacial drift.

Photographed by H. Ashley, The Craigs, Ashtree Road, Costessey, Norwich. April 1838. P.C.

8948.	G. 30.	Old Hunstanton.	Junction of Red and White Chalk, with branching concretions on bedding plane.
8949.	G. 482.	Horsey inundation.	Course of the ‘ hundred streams.’
8950.	G. 479.	Horsey inundation.	Looking inland from S. edge of gap which finally reached length of 500 yards.
8951.	G. 480.	Horsey inundation.	Peat exposed on foreshore by cutting back of beach.
8952.	G. 481.	Horsey inundation.	View from behind temporary defences, looking seaward.

Somerset.—Photographed by F. J. Allen, M.D. (Cantab.), Shepton Mallet (formerly of Mason College, Birmingham). 1894.

8953.	—	Backwell Combe.	Dry valley in Carboniferous Limestone. 6 × 8.
8954.	—	Edge of Worle Hill overlooking Kew Stoke.	Carb. Lst. hill rising from alluvial flat. 6 × 8.
8955.	—	Brean Down.	Southern (scarp) face (Carb. Lst.). 6 × 8.

Photographed by W. J. Arkell, M.A., D.Sc., Hurstcote, Cumnor, Oxford.

8956.	—	Shepton Montague cutting, near Bruton.	Fuller's Earth Rock.

Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol.
½ and ¼.

8957.	04·31.	Winford Quarry.	Millstone Grit overlain by Trias, both highly ferruginous. 1904. ½.
8958.	05·61*.	Wookey.	Mouth of the 'hyæna den.' 1905. ¼.
8959.	31·66.	Top of the Ebbor Gorge.	
8960.	05·2.	Portishead.	Weathered surface of Dolomitic Conglom.
8961.	05·2*.	Portishead.	Weathered surface of Dolomitic Conglom.
8962.	22·43.	Portishead 'new' road, S.E. of Battery Point.	Disturbed K-beds. 1922.
8963.	18·83.	Portishead, shore S. of Battery Point.	Weathered slab of K_2 Bryozoa bed. 1918.
8964.	34·80.	Portishead, bore at Power station.	Contorted K_1 Lst. and shale. 1934.
8965.	34·82.	Portishead, bore at Power station.	Current-bedded Bryozoa bed (K_1). 1934.
8966.	34.84*.	Portishead, bore at Power station.	Block of 'Conglomerate Bed,' 2nd. series. 1934.
8966*.	35·1.	Milton Road Quarry, Wells.	Dol. Conglom. on Carb. Lst. 1935.
8967.	32·49.	Burrington Combe.	Valley of W. twin stream. 1932.
8968.	06·163.	Burrington Combe.	Escarpment of C_1. 1906.
8969.	06·162.	Burrington Combe.	Escarpment of C_2. 1906.
8970.	06·65*.	Burrington Combe.	Block of 'gastropod bed' (K_1). 1906.

SUFFOLK.—Photographed by H. ASHLEY, The Craigs, Ashtree Road, Costessey, Norwich. P.C.

8971.	G. 582.	Ipswich, Bolton & Co., brick-yard.	Infiltration of iron along bedding planes of glacial sands.
8972.	G. 583.	Ipswich, Bolton & Co., brick-yard.	Contorted glacial sand and gravel.
8973.	G. 584.	Ipswich, Bolton & Co., brick-yard.	Fault with small throw in glacial gravel.
8974.	G. 576.	Westleton.	Glacial pebble beds.

WESTMORLAND.—Photographed by T. HAY, Glenridding, Penrith. 1934-38. ½-pl. enlargement.

8975.	10.	Tarn Crag, Helvellyn.	Bedded tuff.
8976.	11.	Between Dollywaggon and Nethermost Pike.	Spherulitic tuff.
8977.	12.	Glenridding beck below Greenside mine.	Breccia.
8978.	13.	Striding Edge, Helvellyn.	
8979.	14.	Caudale Head draining into Kirkstone beck.	Combe formation with V-shaped cut through late terminal moraine.
8980.	16.	Glenridding beck.	Vesicular rhyolite.
8981.	17.	Head of Deepdale.	Moraine mounds.
8982.	18.	Glenridding beck about 1350 ft. O.D.	Spread of flood boulders largely from burst of Keppel Cove dam.
8983.	19.	Glenridding beck.	'Fluting' by pebbles carried down by stream.

8984.	20.	Glenridding beck.	' Fluting ' along line of joint and pot-holing.
8985.	21.	Glenridding beck.	Pot-holes.
8986.	22.	Hayes water (upper end of lake just visible).	Lateral moraine and lines of descent of débris.
8987.	23.	Near foot of Swarth Beck.	Moraine.
8988.	24.	Grisedale valley.	Eroded moraine.
8989.	25.	Glenridding beck near Rattle-beck Cottage.	Boulder clay resting on deltaic deposit.
8990.	26.	Glenridding beck.	Stratified sand in boulder clay.
8991.	27.	Looking across Angle Tarn to S. half of Helvellyn range.	Ice-rounded hills and rock-masses.
8992.	28.	Below Red Tarn, E. side of Helvellyn.	Part of terminal moraine.
8993.	29.	On Patterdale Common about 1,200 ft. O.D.	Roche moutonnée breaking up along cleavage lines.
8994.	30.	Glenridding beck.	Rough plucked rock-surface below boulder clay.
8995.	31.	Grisedale valley, S. side.	Slightly weathered roche moutonnée.
8996.	32.	Near Blowick, Patterdale.	Roche moutonnée.
8997.	33.	Near Blowick, Patterdale.	Roche moutonnée considerably weathered on downhill side.
8998.	34.	Catstycam, S. slope.	Shows lines of descent of débris.
8999.	35.	High Street about 2,500 ft. O.D.	Descending stone streams.
9000.	36.	Tarn Crag.	Solifluction weathering.
9001.	37.	Nethermost Pike.	Large slab weathering.
9002.	38.	St. Sunday top.	Weathering along cleavage and solifluction acting on loose débris.
9003.	39.	Scrubby Crag, E. side of Fairfield top.	Weathering along cleavage.
9004.	40.	Hart Crag, E. side of Fairfield top.	Weathering mainly along cleavage, but partly along bedding planes.
9005.	44.	Hart Crag, E. side of Fairfield top.	Weathering along cleavage and solifluction of scree.
9006.	15.	Swirrel edge, Helvellyn.	Shows lines of descent of eroded material.
9007.	41.	Helvellyn near top.	Solifluction terraces.
9008.	42.	Striding Edge, Helvellyn.	Slab weathering.
9009.	43.	Hart Crag, E. side of Fairfield Top.	Block weathering in coarse tuff.

WILTSHIRE.—Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. 1894. ½ pl. cut down.

9010.	94·1.	Bradford-on-Avon.	Bradford Clay with Forest Marble bands.

Photographed by T. P. BANE, Marlborough. ¼.

9011.	—	Marlborough.	' The Grey Wethers ' (Sarsen Stones)

YORKSHIRE.—Photographed by the late GODFREY BINGLEY, of Leeds. ¼.

9012.	6995.	Angram reservoir, Nidderdale.	Millstone Grit series, shale and sandstone.

Photographed by ?. ½.

9013.	—	Trow Gill, W. Yorks.	Gorge in Carb. Lst.
9014.	—	Trow Gill, W. Yorks.	Gorge in Carb. Lst.

Photographed by Professor L. S. PALMER, D.Sc., University College, Hull. 3 × 2.

9015.	2.	N. edge, Hornsea Mere.	Gravel terrace marking former limit of Mere.
9016.	3.	Dried up W. exit of Hornsea Mere.	Terraces of boulder clay and glacial gravel.
9017.	4.	W. end of Hornsea Mere.	Dense vegetation of the drying-up Mere.
9018.	5.	Skipsea.	Peat bed below reassorted boulder clay.
9019.	7.	Cliffs between Bridlington and Sewerby.	Stratified interglacial sand and gravel between Upper and Middle boulder clays.
9020.	8.	Near Cottingham, Holderness.	Chalk terrace of pre- and interglacial coast line.
9021.	9.	Sewerby.	Interglacial beach.
9022.	11.	Near Bridlington.	Boulder clay on æolian sands, on Sewerby interglacial beach.

WALES.

CAERNARVONSHIRE.—Photographed by J. E. WYNFIELD RHODES, Ph.D., F.I.C., Municipal Technical College, Blackburn. 4 × 3.

9023.	a.	Porth Colman, Lleyn.	Weathering-in of Tertiary dyke traversing Gwna beds.
9024.	b.	Porth Oer, Lleyn.	Contortions in Abererch series.
9025.	c.	Careg-y-defaid, Pwllheli.	Nodular keratophyre.
9026.	d.	Golf course, Porth Dinllaen, Morfa Nevin.	Spilite (pillow lava).
9027.	e.	W. Coast of Bardsey Island.	Gwna beds.
9028.	f.	Porth Caered.	General view of section, Arenig and Cambrian.

DENBIGH.—Photographed by Professor P. G. H. BOSWELL, F.R.S., Imperial College of Science, S. Kensington, S.W.

9029.	28.	Hafodunos Park, Llangerniew.	Schuppen-like topography in disturbed area. ½.
9030.	A.	Quarry on Friddog.	Nantglyn Flags thrust over well-bedded flags. ½.
9031.	B.	Quarry W.S.W. of Camaes, near Llangerniew.	Nantglyn Flags overridden by disturbed beds. ½.
9032.	C.	Quarry on Foel Gasyth.	Crumbling due to faulting between Nantglyn Flags (lft.) and *scanicus* Mudstones (rt.). ½.
9033.	Y.	Foel-caledeiriau Farm, Wenlli.	Section shows alternation of disturbed and undisturbed flags. 8½ × 6½ enlargement.

Photographed by Dr. A. C. Skerl, Imperial College of Science, S. Kensington, S.W.

9034.	D.	T'yn-y-ffordd, near Llangerniew.	Contact of disturbed beds and undisturbed Nantglyn Flags. ¼.

Photographed by Dr. Edmondson Spencer, Imperial College of Science, S. Kensington, S.W.

9035.	Z.	Rhan-hir, ½ m. S.S.W. of Llangerniew.	Disturbed Ludlovian, *nilssoni*-zone. 8½ × 6½ enlargement.
9036.	5.	Foel-caledeiriau Farm, Wenlli.	Puckered and imbricated Ludlovian, *nilssoni*-zone. 8½ × 6½ enlargement.
9037.	6.	Near Camaes, Llangerniew.	Listric surface of thrust Ludlovian flags. 8½ × 6½ enlargement.

Montgomery.—Photographed by R. Parker Smith, Perse School, Cambridge.

9038.	—	Breidden Hills, S. side.	Conglomerate.

Pembroke.—Photographed by G. Macdonald Davies, M.Sc., 63 Beechwood Road, Sanderstead, Surrey. 1930. ¼.

9039.	30·19.	Caerbwdy Bay, St. David's.	Coastal peneplain.
9040.	30·27.	Porth Llawog, Ramsey Is.	Quartz porphyry and volcanic breccias of Carn Llundain.

SCOTLAND.

Banff.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1934. ½-pl. enlargement.

9041.	34·63.	Cruden.	Brick pit in boulder clay.

Dumfries.—Photographed by J. E. Wynfield Rhodes, Ph.D., F.I.C., Municipal Technical College, Blackburn. 1937. 3 × 2.

9042.	1.	Glenkill.	Type section of Glenkiln Shale.
9043.	2.	Hartfell Score, Moffat.	Type section of Hartfell Shale.
9044.	3.	Dobbs Linn, Moffat.	Type section of Birkhill Shale.
9045.	4.	Dobbs Linn, Moffat.	Type section of Birkhill Shale.
9046.	5.	Locharbriggs Quarry, Dumfries.	Desert Sandstone, Permian.
9047.	6.	Enterkinfoot, Dumfries.	Escarpment of Permian lavas with 'greywacke' hills, chiefly Wenlock, behind.
9048.	7.	Polneul Burn, Kirkconnel.	Tait's Marine Band.
9049.	8.	Polneul Burn, Kirkconnel.	Coal Measures unconformable on Silurian 'greywacke.'
9050.	9.	Polneul Burn, Kirkconnel.	Coal Measures, unconformable on Silurian 'greywacke.'
9051.	10.	Polneul Burn, Kirkconnel.	Coal Measures unconformable on Silurian 'greywacke.'

Inverness.—Photographed by B. Redford, 19 Summerhill Street, Newcastle-on-Tyne. ½-pl. enlargement, 1936.

9052.	1.	Skye, Sgurr-nan-Gillean.	Gabbro mountain.
9053.	2.	Skye, Blaven.	Gabbro mountain.
9054.	3.	Skye, Quiraing.	Basalt mountain.

Photographed by T. Hay, Glenridding, Penrith. ½-pl. enlargement.

9055.	4.	Glamaig.	Granophyre mountain. 1936.
9056.	5.	Cuillins and Loch Coruisk.	Gabbro mountains. 1936.
9057.	6.	Macleod's Tables.	Flat-topped basalt hill. 1936.
9058.	7.	Ben Nevis.	From the Caledonian Canal. 1937.
9059.	8.	Upper falls, Glen Nevis.	Waterfall from hanging valley. 1937.
9060.	9.	Glen Nevis.	Roches moutonnées. 1937.

Kincardine.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1912. ¼.

9061.	12·45.	Cowie.	Honeycomb weathering of Downtonian Sandstone.
9062.	12·37.	Dunnottar Castle.	Stands on cliff of Old Red Conglom.

Sutherland.—Photographed by A. G. Stenhouse, 191 Newhaven Road, Edinburgh. 1937. ½.

9063.	B. 1.	By Loch Assynt on S. slopes of Quinag.	Unconformity, Cambrian quartzite on Torridonian.
9064.	E. 3.	On roadside just E. of Knochan cliff.	Thrust-plane.
9065.	E. 5.	Knochan cliff.	Moine Thrust.
9066.	A. 5.	Loch Assynt, N. side.	Torridonian unconformable on Lewisian.
9067.	D. 7.	Stack of Glencoul.	The Stack (Moine Schist) is thrust forward about 10 m. by the Moine Thrust.
9068.	D. 5.	Glencoul.	Near view of Glencoul Thrust bringing Lewisian over Cambrian.

Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1936. ¼.

9069.	36·77.	Strath Vagistie, 1½ m. S. of Altnaharra.	Pencil-jointed Moines.
9070.	36·76.	Ben Loyal, Tongue.	Syenite with inclusions.

IRELAND.

Antrim.—Photographed by Hallam Ashley, The Craigs, Ashtree Road, Costessey, Norwich. P.C.

9071.	G. 196.	Craigs Moss, E. side of road Ballymena to Kilrea.	Stump of pine tree in peat. 1934.
9072.	G. 438.	Craigs, near Culleybackey.	Hummocky drift. 1938.
9073.	G. 428.	Craigs Moss, between Culleybackey and Rasharkin.	Peat cutting.
9074.	G. 453a.	Kinmeen between Ballycastle and Carrick-a-Rede.	Columnar and irregularly jointed basalt.

9075.	G. 455.	Ballysillon near Belfast.	Basalt dyke cutting Chalk.
9076.	G. 439.	Fair Head.	Laccolitic intrusion of columnar dolerite.
9077.	G. 430.	Tardree quarry.	Columnar rhyolite.
9078.	G. 443.	Tardree quarry.	Columnar rhyolite.
9079.	G. 444.	Ballyemon Glen.	Spheroidal basalt.
9080.	G. 456.	Ballycastle, Colliery Bay.	Carboniferous section.
9081.	171.	Portrush.	Indurated Lias shale.
9082.	528.	W. side of Long Mountain.	Irregularly jointed basalt.
9083.	G. 523.	Ballyemon Glen, N. side.	Conglomeratic base of Chalk overlain by normal Chalk.
9084.	170.	Craigs near Hillmount works.	Section of glacial drift.
9085.	434.	Near Pollan bridge on Glendun river.	Meanders of stream.
9086.	G. 524.	Dunstown, near Glarryford.	Drumlins.
9087.	432.	Between Milltown and Moneyglas.	Drumlin country.

Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1935. $\frac{1}{4}$.

9088.	35·43.	Lough-a-veema.	Sun-cracks and terraces in the drying-up lake.
9089.	35·44.	Lough-a-veema.	Sun-cracks and terraces in the drying-up lake.

Clare.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1938.

9090.	38·26.	The shore, Black Head.	Griked Carb. Lst. with erratics. $\frac{1}{4}$.
9091.	38·27.	The shore, Black Head.	Griked Carb. Lst. with erratics. $\frac{1}{4}$.
9092.	38·28.	The Burren.	Distant view of bare Carb. Lst. hills. $\frac{1}{4}$.
9093.	38·29.	The Burren.	Distant view of bare Carb. Lst. hills. $\frac{1}{4}$.
9094.	38·25.	Black Head.	Bare Carb. Lst. country. $\frac{1}{2}$-pl. enlargement.
9095.	38·18.	Kilkee.	Blowhole. $\frac{1}{4}$.
9096.	38·17.	Kilkee.	Rippled Carboniferous flags. $\frac{1}{4}$.
9097.	38·13*.	Ross, Kilkee.	Coast erosion, natural arch. $\frac{1}{4}$.
9098.	38·15.	Ross, Kilkee.	Coast erosion, natural arch. $\frac{1}{4}$.
9099.	38·14.	Ross, Kilkee.	Coast erosion. $\frac{1}{4}$.
9100.	38·16.	Ross, Kilkee.	Coast erosion. $\frac{1}{4}$.

Down.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1902. $\frac{1}{4}$.

9101.	02·185.	Near Rostrevor.	The Clogh Mor.

Tipperary.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. 1938. $\frac{1}{4}$.

9102.	38·49.	Rock of Cashel from N.E.	Carboniferous Limestone.

SECTION E (GEOGRAPHY)

A NATIONAL ATLAS

REPORT of the COMMITTEE appointed to prepare a scheme for a projected National Atlas of Great Britain and Northern Ireland (Prof. E. G. R. Taylor, Chairman ; Dr. S. W. Wooldridge, Secretary ; Dr. E. B. Bailey, F.R.S., Dr. G. Daniel, Dr. H. C. Darby, Prof. F. Debenham, Capt. C. Diver, Prof. H. J. Fleure, F.R.S., Mr. D. L. Linton, Brig. M. N. MacLeod, Prof. E. J. Salisbury, F.R.S., Prof. A. G. Tansley, F.R.S.).

At the Cambridge Meeting, Section E (Geography) took the initiative in asking for a joint Committee of the various sections interested to explore the possibility and desirability of producing a National Atlas of Great Britain and Northern Ireland, or alternatively of the British Isles. The Committee has received the active co-operation and assistance of Prof. K. Mason, Dr. L. D. Stamp, Mr. E. W. Gilbert, and Mr. C. F. W. R. Gullick.

The proposed atlas aims at a strictly objective and scientific presentation of the natural conditions, natural resources and economic development of Britain (and the adjacent seas), of the history and pre-history of the country, and of the distribution, occupations, movement and social conditions of the population. It is believed that the publication of such an atlas would mark a great step forward in the dissemination of accurate knowledge of this country among the general public. It would also be of service to administrators, public men, educationists, and research workers in many fields, since it would present in convenient form the data upon which many conclusions, and decisions of national importance, must be based.

The National Atlas would present for the first time on a uniform cartographic plan the results of the various surveys, returns and censuses made by Government departments ; those for example of the Ministry of Agriculture, the Ministry of Labour, the Air Ministry and the Registrar-General's department. In addition, much further material exists, gathered by research workers in particular fields—by geologists, meteorologists, archæologists, historians, sociologists, biologists and geographers, to mention but a few. The proposed collation and presentation in cartographical form of these scattered data would be of the very greatest value.

An enterprise of such scope and importance should be entitled to support from public funds, but its success from a scientific standpoint must depend on scientific workers and scientific bodies being willing to undertake responsibility for the accuracy of maps within particular fields.

The scheme as here presented is not to be regarded as necessarily in final form. The details are evidently subject to revision. It has seemed worth while, nevertheless, to put it forward, in the hope that it may receive constructive criticism.

By its terms of reference the Committee was limited to the consideration of an atlas for Great Britain and Northern Ireland. From many points of view it was evidently desirable that such an atlas should treat of the British Isles as a whole, and of their constituent parts. The following arrangements of loose-leaf sheets might therefore prove possible.

1. *Atlas of England and Wales.* 100 *Double Plates.*
   Contents : 40 Plates of British Isles.
   60 Plates of England and Wales.

2. *Atlas of Scotland.* 70 *Double Plates.*
   Contents : 40 Plates of British Isles (as for England and Wales).
   30 Plates of Scotland.

3. *Atlas of Ireland* (Eire and N.E. Ireland). 60 Double Plates.
   Contents : 40 Plates of British Isles.
   20 Plates of Ireland.

   (Alternative to 2 and 3.)
4. *Atlas of Scotland and N.E. Ireland.* 70 Double Plates.
   Contents : 40 Plates of British Isles.
   30 Plates of Scotland and N.E. Ireland.
5. *Atlas of the British Isles.* 140 Double Plates (2 vols.).
   Contents : 40 Plates of British Isles.
   60 Plates of England and Wales.
   30 Plates of Scotland.
   10 Plates of Ireland.
6. *Atlas of the British Isles.* 130 Double Plates (2 vols.).
   Contents : 40 Plates of British Isles.
   60 Plates of England and Wales.
   30 Plates of Scotland and N.E. Ireland.

The numbers of plates are, of course, provisional only. For an indication of the probable sizes of the maps, see Section B (Bio-Geography) below.

The Committee has worked upon the basis of the following general scheme of sub-divisions for the proposed atlas.

A. Physical Geography.
   - i. Cartography.
   - ii. Orography.
   - iii. Geology.
   - iv. Climatology.
   - v. Hydrography.

B. Bio-Geography.

C. Industry and Commerce.

D. Human Geography.
   - i. Archæology and Pre-History.
   - ii. Historical Geography.
   - iii. Political Geography.
   - iv. Strategic Geography.
   - v. Vital Statistics.
   - vi. Social Geography.

Some of these sections have been worked out by sub-committees or individuals in fuller detail. Where such details are not at present available a general statement covering the section in question is made below. It should be noted that the details have more explicit reference to that part of the proposed atlas which would deal with England and Wales. This has been done for convenience only. The Committee hesitated to make detailed suggestions for Scotland and Ireland pending full discussion with Scottish and Irish colleagues. Some of the data can and should be treated for the British Isles as a whole, but special Scottish and Irish sections would require separate study and consideration.

A. Physical Geography.

A*i* and A*ii*. *Cartography and Orography.*

Maps to illustrate the work of the Ordnance Survey, the triangulation of the country, etc., and its relief features.

A*iii*. *Geology.*

Geological map (stratigraphical).

Geological map (lithological, with generalised drift boundaries).
Map to show distribution of drift deposits (if and when available).

A series of maps to show the palæo-geographic evolution of the country (including glaciation).

Maps showing dominant structural features and vulcanicity.

Morphological map (with insets of sample regions).

Maps to show the distribution of coal- and iron-bearing rocks, metallogenetic provinces and certain aspects of water-supply.

A*iv*. *Climatology*.

Maps to show the distribution and variation of temperature, pressure, rainfall, wind, sunshine, relative humidity, thunder, fog, etc.

Maps to illustrate the leading weather types.

Maps to illustrate phenological data.

[*Note*.—The details of this section would be settled in consultation with the Royal Meteorological Society and the Air Ministry.]

A*v*. *Hydrography*.

Maps to show submarine topography of British seas, bottom deposits, types of coastline, surface salinities and temperatures (with sections for features in depth), tidal phenomena and navigation data.

Maps, sections and graphs to illustrate river régimes.

B. Bio-Geography.

The details of this section have been worked out in full and are given below as an example of the general style of treatment envisaged by the Committee. It is assumed that a single page of the atlas will have minimum dimensions of 21 × 14 in.

Soil.

Pl. I. British Isles adapted from Stremme's soil map of Europe.
Pl. II. 3 maps (1 in. to mile) of selected areas, one drift map of one of these areas for comparison (10 × 7 in.).
Pl. III. 4 maps (10 × 7 in.) of larger districts showing distribution of drift.

Vegetation.

Pl. IV. }
Pl. V. } British Isles (28 × 21 in.) showing distribution of certain localised types of vegetation.
Pl. VI. Part of the Peak district (1 in. to mile) showing zonation of vegetation and line contours.
Pl. VII. 4 maps (10 × 7 in.) of selected districts (1 in. to mile).

Distribution of species.

Pl. VIII. British Isles, 16 maps (5 × 3½ in.), showing distribution of individual plant species.
Pl. IX. British Isles, 16 maps (5 × 3½ in.), showing distribution of individual land animal species.
Pl. X. }
Pl. XI. } Western Europe, 8 maps (10 × 7 in.), showing total range of certain British plants and animals.
Pl. XII. British Isles, several maps, showing spread of species in historical or recent times.
Pl. XIII. Western Europe, several maps, showing seasonal migration routes, seasonal migration on broad fronts or seasonal occupation areas of certain birds.
Pl. XIV. }
Pl. XV. } Great Britain, several maps, showing densities of various 'game crops.'

Pl.	XVI.	British Isles, several maps, showing distribution of freshwater animals and plants.
Pl. Pl.	XVII. XVIII.	Western Europe from Spitsbergen to Portugal, showing distribution of trawl fisheries.
Pl.	XIX.	British Isles, showing distribution of drift-net fisheries (mainly herring).

Pre-History.

Pl.	XX.	British Isles. Probably 4 maps, showing distribution of tree pollen of different species in different post glacial epochs.

Land Utilisation.

Pl. Pl.	XXI. XXII.	England and Wales (28 × 21 in.).
Pl. Pl.	XXIII. XXIV.	Scotland (28 × 21 in.).
Pl.	XXV.	Ireland (21 × 14 in.).
Pl.	XXVI.	4 maps (10 × 7 in.) of selected areas (1 in. to mile).
Pl.	XXVII.	Great Britain, ' Fertility ' (21 × 14 in.).

Forestry.

Pl. Pl.	XXVIII. XXIX.	Great Britain, map of Forestry Commission estates with any practicable details.

Agriculture.

Pl.	XXX.	England and Wales. Map showing types of farming.
Pl. Pl. Pl. Pl.	XXXI. XXXII. XXXIII. XXXIV.	Several ' dot maps ' of British Isles, Great Britain, or England and Wales, showing distribution of different farm crops and farm animals.

C. Industry and Commerce.

Ci *Coal and Iron.*	Coalfields, exposed and concealed. Individual coalfields, size graded according to employment. Output and export trade. Iron-ore production. Blast furnaces, coke ovens, steel works, etc.
Cii *Non-Ferrous Minerals.*	Mines and centres of production distinguished according to employment/output. Smelters, etc. Brickworks, Cement works, etc., distinguished according to employment/output.
Ciii *Electricity, Petroleum and Coal Gas.*	Generating stations (? installed h.p.) and grid. Importing ports, refineries, storage, l.t. and h.t. carbonisation plants, etc. Centres of production and output.
Civ *Roads, Waterways, Airways and Railways.*	Trunk, A and B (?) roads. Bus services according to density. Canals and navigable rivers, indicating depth and gauge. (?) Traffic density. Routes and density. Operating companies, electric railways, number of tracks (2+, 2, 1). Areas 4 miles distant from railways. Distinction of passenger and goods lines.

Cv *Ports.* Tonnage of shipping and merchandise at individual ports. Indication of size of shipping which can be berthed, and special facilities available (e.g. coal staithes, cold storage, fish docks, train ferry, etc.).
Accessibility by rail.

Cvi *Accessibility* by rail from principal centres according to distance and time.
E.g. London, Birmingham, Liverpool, Manchester, Leeds, Newcastle, Swansea, Bristol, Plymouth, Norwich.

Cvii *Finance.* Distribution of banks, stock exchanges, commodity exchanges, foreign trade, etc.

Cviii *Individual Industries* according to employment/output.
E.g. textiles, engineering, fisheries, food and drink, trading estates.
The number of industries to be mapped to depend on space available.

D. Human Geography.

Di. *Archæology and Pre-History.*

England and Wales in Palæolithic times : (A) the Lower and Middle Palæolithic cultures ; (B) the Upper Palæolithic cultures. Two maps on one plate : restricted to England and Wales because no Palæolithic material is known from Ireland and Scotland. The extent of the last Glaciation to be marked on map B, and four inset maps at the bottom with the phases of Pleistocene glaciation in southern Britain.

The British Isles : Mesolithic cultures. Map of finds dating between 8,000 and 2,500 B.C. based on J. G. D. Clark's maps. Inset maps of Goodwin's polenanalytical data for Boreal and for Atlantic.

The British Isles : Distribution map of Megalithic cultures. Small insets of (*a*) Windmill Hill culture, and (*b*) Peterborough pottery.

The British Isles : The Beaker cultures. With insets of Early Bronze Age trade, and of the Wessex Early Bronze Age culture, and The British Isles : Map of Massed Bronze Age finds based on Miss L. F. Chitty's map in the Personality of Britain.

Maps of Great Britain to illustrate Late Bronze Age and Early Iron Age A cultures.

Maps of Great Britain to illustrate Early Iron Age B and C cultures, also towns and Celtic tribes in the immediately pre-Conquest period.

Dii. *Historical Geography.*

1–2. *Roman Britain.*

Note : The existing Ordnance Survey map.

3. *England and Wales : The Dark Ages.*

Note : A smaller version of the existing Ordnance Survey map.

4. England and Wales Political : (*a*) *Circa* A.D. 700
(*b*) *Circa* A.D. 900

Note : Possibly other dates might be chosen, but these seem representative.

5–6. *Place-name Elements.*

Note : Until the work of the Place-Name Society is completed, this raises many problems especially in the case of Anglo-Saxon elements. Scandinavian elements might more easily lend themselves to plotting.

7–10. *Agriculture.*

7*a*. Domesday Arable (Plough teams).
7*b*. Domesday Woodland.
8. Field Systems : Outline map ; Fourteenth Century. Low-price Wheat Areas ; and sample types of Field Systems in diagrammatic form.
9*a*. Enclosures in Sixteenth Century.
9*b*. Land enclosed at end of Sixteenth Century.
10*a*. Land enclosed at end of Seventeenth Century.
10*b*. Enclosures by Act of Parliament.

11–17. *Population.*

11*a*. Domesday Manors.
11*b*. Domesday Population Averages.
12*a*. Fourteenth Century Population.
12*b*. Sixteenth Century Population.
13*a*. Seventeenth Century Population.
13*b*. Population in 1701.
14*a*. „ „ 1801.
14*b*. „ „ 1821.
15*a*. „ „ 1851.
15*b*. „ „ 1871.
16. The Growth of London.
17. Representative Population Graphs for the Nineteenth Century.

Note : (*a*) Possibly it might be better to include a series of smaller maps to show population for *every* Census between 1801–1931.
(*b*) The Representative Graphs would illustrate conditions in selected rural and urban areas.

18–20. *Ecclesiastical.*

18*a*. Dioceses : 780.
18*b*. „ Edward I.
19*a*. „ 1539.
19*b*. „ 188.
20. Nonconformist Distributions in the Nineteenth Century.

Note : Possible additions under this section :
(1) A map of Irish and Roman Christianity in the British Isles (this might be an inset).
(2) A map of Monasteries.

21. *Wales.*

(i) Political *Circa* 1200.
(ii) „ „ 1284.
(iii) „ „ 1536.
(iv) Social and Economic (Manors, Boroughs, Welsh Districts).

Note : (*a*) Separate treatment is suggested for Wales to illustrate the Anglo-Welsh boundaries, etc.
(*b*) A desirable addition to this section would be a series of maps illustrating conditions 800 to 1066.

22–26. *Industrial and Commercial.*

22*a*. Thirteenth and Fourteenth Centuries.
22*b*. Eighteenth Century.
23. Nineteenth Century.
24*a*. Canals (e.g., see Phillips Waterways 1795).

24*b*. Turnpike Roads.
25. Series of maps (say 4) showing Railway Development.
26. Foreign Trade maps (Mediæval and later).

Note : (*a*) The maps on sheet 22 would in each case show Minerals and Textiles, either separately or together.
(*b*) Sheet 23 should include the 1851 Census map of Occupations.
(*c*) Sheet 24*b* might include an inset map of the Fourteenth Century Roads.

27. *Parliamentary Representation.*
25*a*. Down to 1832.
25*b*. After the Act of 1832.

D*iii*. *Political Geography.*

Administrative.

1. The administrative counties and seats of county councils.
2. The rural districts and urban districts.
3. The county boroughs and municipal boroughs.

Justice.

4. The Assize circuit and Assize towns.
5. The county circuits.
6. Dot map of prisons.

Religion.

7. The Church of England dioceses with cathedral towns.
8. The Roman Catholic dioceses with cathedral towns.
9. Certain Nonconformist areas.

Political.

10. Parliamentary electoral divisions with a series of maps showing distribution of parties at certain general elections : (?) (1) 1910, (2) 1918, (3) 1923, (4) 1931.
11. (?) A map of political parties in the county boroughs.

D*iv*. *Strategic Geography.*

1. Army Commands and garrison towns.
2. Naval depots and dockyards.
3. R.A.F. Commands and stations, and Civil Air Guard stations.
4. Civil Defence regions, 1939.

D*v*. *Vital Statistics.*

Maps to show population density, sizes of towns, occupied persons (by classes), and unemployment.

D*vi*. *Social Geography.*

Health and Recreation.

1. Hospital regions with number of hospitals, mental hospitals by different symbols.
2. Inland spas and seaside watering places.
3. National fitness areas.
4. Youth hostels.

Amenities.

1. Town Planning regions.
2. National Trust properties.
3. Schedule of Ancient Monuments.
4. Office of Works properties.
5. Proposed National Parks, (?) combined with existing Green Belts, bird sanctuaries and Crown lands (New Forest, etc.).

Labour.

1. Administrative divisions of Employment Exchange Service and Employment Exchange areas with administrative centres.
2. Trade Unions, regional divisions.
3. The special areas.

Communications and Transport.

1. Telephone areas with headquarters.
2. Post Office regions.
3. B.B.C. stations.
4. Ministry of Transport traffic areas.
5. A.A. regions and R.A.C. regions.

Education.

1. Board of Education, Inspectorate areas.
2. Dot map of Schools on Headmasters' conference.
3. ,, ,, of other Secondary Schools.
4. ,, ,, of Training Colleges.
5. ,, ,, of Universities and University Colleges with dates of foundation.
6. Towns with daily and evening newspapers.

Agriculture.

1. Milk Marketing regions.
2. Advisory provinces of Ministry of Agriculture.
3. Agricultural divisions of Ministry of Agriculture.

The Committee ventures to hope that the Sections and Council of the British Association will make recommendations which will secure the further progress of the plan; more especially with a view to determining by what means the project may be put into execution. Although the details as here submitted are frankly tentative, the Committee has received ample evidence of wide and hearty support for the plan in general and is of opinion that further immediate action is called for.

RESEARCH COMMITTEES, Etc. 1939–40

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

Seismological investigations.—Prof. H. H. Plaskett, F.R.S. (*Chairman*), Mr. J. J. Shaw, C.B.E. (*Secretary*), Miss E. F. Bellamy, Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. E. C. Bullard, Dr. A. T. J. Dollar, Dr. A. E. M. Geddes, O.B.E., Prof. G. R. Goldsbrough, F.R.S., Dr. Wilfred Hall, Mr. J. S. Hughes, Dr. H. Jeffreys, F.R.S., Mr. Cosmo Johns, Dr. A. W. Lee, Prof. E. A. Milne, M.B.E., F.R.S., Prof. H. C. Plummer, F.R.S., Prof. J. Proudman, F.R.S., Dr. A. O. Rankine, O.B.E., F.R.S., Rev. C. Rey, S. J., Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, F.R.S., Mr. F. J. Scrase, Capt. H. Shaw, Sir Frank Smith, G.B.E., K.C.B., Sec. R.S., Dr. Stagg, Dr. R. Stoneley, F.R.S., Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S., Dr. F. J. W. Whipple. **£100** (Caird Fund).

Calculation of mathematical tables.—Prof. E. H. Neville (*Chairman*), Dr. A. J. Thompson (*Vice-Chairman*), Dr. J. Wishart (*Secretary*), Dr. W. G. Bickley, Prof.

R. A. Fisher, F.R.S., Dr. J. Henderson, Dr. E. L. Ince, Dr. J. O. Irwin, Dr. J. C. P. Miller, Prof. L. M. Milne-Thomson, Mr. F. Robbins, Mr. D. H. Sadler, Mr. F. Sandon, Mr. W. L. Stevens, Dr. J. F. Tocher, Mr. M. V. Wilkes. **£100** (Caird Fund).

SECTIONS A, C.—MATHEMATICAL AND PHYSICAL SCIENCES, GEOLOGY.

The direct determination of the thermal conductivities of rocks in mines or borings where the temperature gradient has been, or is likely to be, measured—Dr. Ezer Griffiths, F.R.S. (*Chairman*), Dr. D. W. Phillips (*Secretary*), Dr. E. C. Bullard, Dr. H. Jeffreys, F.R.S. (*from Section A*) ; Dr. E. M. Anderson, Prof. W. G. Fearnsides, F.R.S., Prof. G. Hickling, F.R.S., Prof. A. Holmes, Dr. J. H. J. Poole (*from Section C*).

SECTION C.—GEOLOGY.

To investigate the relation of the Silurian to the Archæan in the Herefordshire Beacon, Malvern Hills.—Prof. W. G. Fearnsides, F.R.S. (*Chairman*), Dr. A. Bramwell (*Secretary*), Prof. H. L. Hawkins, F.R.S., Prof. V. C. Illing, Dr. R. W. Pocock, Prof. H. H. Read, F.R.S. **£25** (Bernard Hobson Fund).

To excavate critical geological sections in Great Britain.—Prof. W. T. Gordon (*Chairman*), Prof. W. G. Fearnsides, F.R.S. (*Secretary*), Prof. E. B. Bailey, F.R.S., Mr. H. C. Berdinner, Mr. W. S. Bisat, Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. W. S. Boulton, Prof. A. H. Cox, Miss M. C. Crosfield, Mr. E. E. L. Dixon, Dr. Gertrude Elles, M.B.E., Mr. C. I. Gardiner, Prof. E. J. Garwood, F.R.S., Mr. F. Gossling, Prof. H. L. Hawkins, F.R.S., Prof. G. Hickling, F.R.S., Dr. R. G. S. Hudson, Prof. V. C. Illing, Prof. O. T. Jones, F.R.S., Dr. Murray Macgregor, Dr. F. J. North, Dr. J. Pringle, Prof. S. H. Reynolds, Sir Franklin Sibly, Dr. W. K. Spencer, F.R.S., Dr. W. E. Swinton, Prof. A. E. Trueman, Dr. F. S. Wallis, Prof. W. W. Watts, F.R.S., Dr. W. F. Whittard, Sir A. Smith Woodward, F.R.S., Dr. S. W. Wooldridge. **£20** (Bernard Hobson Fund).

To consider and report upon petrographic classification and nomenclature.—Lt.-Col. W. Campbell Smith (*Chairman and Secretary*), Prof. E. B. Bailey, F.R.S., Dr. R. Campbell, Dr. W. Q. Kennedy, Dr. A. G. MacGregor, Prof. S. J. Shand, Mr. S. J. Tomkeieff, Dr. G. W. Tyrrell, Dr. F. Walker, Dr. A. K. Wells.

To consider and report on questions affecting the teaching of geology in schools.—Prof. W. W. Watts, F.R.S. (*Chairman*), Prof. A. E. Trueman (*Secretary*), Prof. P. G. H. Boswell, O.B.E., F.R.S., Mr. C. P. Chatwin, Prof. A. H. Cox, Mr. J. Davies, Miss E. Dix, Miss Gaynor Evans, Prof. W. G. Fearnsides, F.R.S., Prof. G. Hickling, F.R.S., Prof. D. E. Innes, Prof. A. G. Ogilvie, O.B.E., Prof. W. J. Pugh, Mr. J. A. Steers, Prof. H. H. Swinnerton, Dr. A. K. Wells.

The collection, preservation, and systematic registration of photographs of geological interest.—Prof. E. J. Garwood, F.R.S. (*Chairman*), Prof. S. H. Reynolds (*Secretary*), Mr. H. Ashley, Mr. G. Macdonald Davies, Mr. J. F. Jackson, Dr. A. G. MacGregor, Dr. F. J. North, Dr. A. Raistrick, Mr. J. Ranson, Prof. W. W. Watts, F.R.S.

SECTION D.—ZOOLOGY.

To nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Dr. W. T. Calman, C.B., F.R.S. (*Chairman and Secretary*), Prof. H. Munro Fox, F.R.S., Dr. J. S. Huxley, F.R.S., Prof. H. G. Jackson, Prof. W. M. Tattersall, Prof. C. M. Yonge. **£50.**

To co-operate with other sections interested, and with the Zoological Society for the purpose of obtaining support for the Zoological Record—Sir Sidney Harmer, K.B.E., F.R.S. (*Chairman*), Mr. J. R. Norman (*Secretary*), Prof. E. S. Goodrich, F.R.S., Dr. O. W. Richards. **£50.**

To investigate the density of living organisms.—Dr. S. W. Kemp, F.R.S. (*Chairman*), Mr. A. G. Lowndes (*Secretary*), Prof. R. A. Fisher, F.R.S., Dr. C. F. A. Pantin, Dr. F. S. Russell. **£30.**

To investigate sex in salmon.—Prof. F. A. E. Crew (*Chairman*), Prof. J. H. Orton, Prof. J. Ritchie. **£25.**

To study the progressive adaptation to new conditions in *Artemia salina* (Diploid and Octoploid, Parthenogenetic *v.* Bisexual).—Prof. R. A. Fisher, F.R.S. (*Chairman*), Mr. A. C. Fabergé (*Secretary*), Dr. F. Gross, Mr. A. G. Lowndes, Dr. K. Mather, Dr. E. S. Russell, O.B.E., Prof. D. M. S. Watson, F.R.S. **£20.**

To study insular faunas.—Prof. Sir E. B. Poulton, F.R.S. (*Chairman*), Prof. G. D. Hale Carpenter (*Secretary*), Prof. H. G. Jackson, Capt. N. D. Riley. **£10.**

To consider the position of animal biology in the school curriculum and matters relating thereto.—Prof. R. D. Laurie (*Chairman and Secretary*), Mr. P. Ainslie, Dr. H. W. Cousins, Dr. J. S. Huxley, F.R.S., Mr. Percy Lee, Mr. A. G. Lowndes, Prof. E. W. MacBride, F.R.S., Dr. W. R. Spencer, F.R.S., Prof. W. M. Tattersall, Dr. E. N. Miles Thomas.

SECTIONS D, E, K.—ZOOLOGY, GEOGRAPHY, BOTANY.

To assist in the preservation of Wicken Fen.—Prof. F. T. Brooks, F.R.S. (*Chairman*), Dr. H. Godwin (*Secretary*), Prof. F. Balfour-Browne, Dr. H. C. Darby, Prof. J. Stanley Gardiner, F.R.S., Mr. J. A. Steers, Dr. W. H. Thorpe, Dr. D. Valentine. **£20.**

SECTIONS D, I, K.—ZOOLOGY, PHYSIOLOGY, BOTANY.

To aid competent investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.—Prof. E. W. MacBride, F.R.S. (*Chairman and Secretary*), Prof. Sir J. Barcroft, C.B.E., F.R.S., Dr. Margery Knight, Dr. J. Z. Young.

SECTIONS D, J.—ZOOLOGY, PSYCHOLOGY.

To conduct field experiments on bird behaviour.—Dr. J. S. Huxley, F.R.S. (*Chairman*), Mr. F. B. Kirkman (*Secretary*), Prof. F. Aveling, Dr. C. S. Myers, C.B.E., F.R.S., Dr. E. S. Russell. **£40.**

SECTIONS D, K.—ZOOLOGY, BOTANY.

To aid competent investigators selected by the Committee to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Windermere.—Prof. F. E. Fritsch, F.R.S. (*Chairman*), Dr. E. B. Worthington (*Secretary*), Prof. P. A. Buxton, Miss P. M. Jenkin, Dr. C. H. O'Donoghue (*from Section D*) ; Dr. W. H. Pearsall (*from Section K*). **£75.**

Co-ordinating committee for Cytology and Genetics.—Prof. F. T. Brooks, F.R.S. (*Chairman*), Dr. D. G. Catcheside (*Secretary*), Mr. E. B. Ford, Prof. F. A. E. Crew, Dr. C. D. Darlington, Prof. R. A. Fisher, F.R.S., Prof. R. R. Gates, F.R.S., Dr. C. Gordon, Prof. Dame Helen Gwynne Vaughan, G.B.E., Dr. J. Hammond, Dr. J. S. Huxley, F.R.S., Dr. T. J. Jenkin, Mr. W. J. C. Lawrence, Dr. F. W. Sansome, Dr. W. B. Turrill, Dr. C. H. Waddington, Dr. D. M. Wrinch.

SECTION E.—GEOGRAPHY.

To prepare a scheme for a projected National Atlas of Great Britain and Northern Ireland.—Prof. E. G. R. Taylor (*Chairman*), Dr. S. W. Wooldridge (*Secretary*), Dr. H. C. Darby, Prof. F. Debenham, Mr. C. Diver, Prof. H. J. Fleure, F.R.S., Mr. D. L. Linton, Brig. M. N. MacLeod, Prof. E. J. Salisbury, F.R.S., Prof. A. G. Tansley, F.R.S.

To collect and record information on demography and seasonal activities in relation to environment in Inter-Tropical Africa—Prof. P. M. Roxby (*Chairman*), Prof. A. G. Ogilvie, O.B.E. (*Secretary*), Mr. S. J. K. Baker, Prof. C. B. Fawcett, Prof. H. J. Fleure, F.R.S., Prof. C. Daryll Forde, Mr. R. H. Kinvig, Mr. J. McFarlane, Prof. J. L. Myres, O.B.E., Mr. R. A. Pelham, Mr. R. U. Sayce.

To consider and report upon ambiguities and innovations in geographical terminology.—Prof. E. G. R. Taylor (*Chairman*), Dr. S. W. Wooldridge (*Secretary*), Mr. H. King, Mr. R. H. Kinvig.

To co-operate with bodies concerned with the cartographic representation of population, and in particular with the Ordnance Survey, for the production of population maps.— (*Chairman*), Prof. C. B. Fawcett (*Secretary*), The Director General of the Ordnance Survey, Col. Sir Charles Close, K.B.E., C.B., C.M.G., F.R.S., Prof. H. J. Fleure, F.R.S., Mr. A. C. O'Dell, Mr. A. Stevens, Mr. A. V. Williamson.

SECTION G.—ENGINEERING.

To review the knowledge at present available for the reduction of noise, and the nuisances to the abatement of which this knowledge could best be applied.— (*Chairman*), Wing-Commander T. R. Cave-Browne-Cave, C.B.E. (*Secretary*), Dr. A. H. Davis, Prof. G. W. O. Howe, Mr. E. S. Shrapnell-Smith, C.B.E.

Electrical terms and definitions.—Prof. Sir J. B. Henderson (*Chairman*), Prof. F. G. Baily and Prof. G. W. O. Howe (*Secretaries*), Prof. W. H. Eccles, F.R.S., Prof. C. L. Fortescue, Prof. E. W. Marchant, Prof. J. Proudman, F.R.S., Sir Frank Smith, G.B.E., K.C.B., Sec. R.S., Prof. L. R. Wilberforce.

SECTION H.—ANTHROPOLOGY.

To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern. —Sir A. Keith, F.R.S. (*Chairman*), Prof. J. L. Myres, O.B.E. (*Secretary*), Mr. M. C. Burkitt, Miss D. A. E. Garrod, Mr. A. D. Lacaille. **£25.**

To co-operate with a Committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Prof. H. J. Fleure, F.R.S., Miss D. A. E. Garrod, Dr. J. Wilfred Jackson, Prof. L. S. Palmer, Mr. H. J. E. Peake. **£12 10s.** (and **£12 10s.** Contingent).

To report on the composition of ancient metal objects.—Mr. H. J. E. Peake (*Chairman*), Dr. C. H. Desch, F.R.S. (*Secretary*), Mr. H. Balfour, F.R.S., Prof. V. G. Childe, Mr. O. Davies, Prof. H. J. Fleure, F.R.S., Mr. C. Hawkes, Miss W. Lamb, Mr. M. E. L. Mallowan, Mr. H. Maryon, Dr. A. Raistrick, Dr. R. H. Rastall. **£5 16s. 6d.**

To investigate early mining sites in Wales.—Mr. H. J. E. Peake (*Chairman*), Mr. Oliver Davies (*Secretary*), Dr. C. H. Desch, F.R.S., Mr. E. Estyn Evans, Prof. H. J. Fleure, F.R.S., Prof. C. Daryll Forde, Sir Cyril Fox, Dr. Willoughby Gardner, Dr. F. J. North, Mr. V. E. Nash Williams.

To investigate blood groups among primitive peoples.—Prof. H. J. Fleure, F.R.S. (*Chairman*), Prof. R. Ruggles Gates, F.R.S. (*Secretary*), Dr. F. W. Lamb, Dr. G. M. Morant.

To co-operate with a committee of the Royal Anthropological Institute in assisting Miss G. Caton-Thompson to investigate the prehistoric archæology of the Kharga Oasis.—Prof. J. L. Myres, O.B.E. (*Chairman*), Miss G. Caton-Thompson (*Secretary*), Dr. H. S. Harrison, Mr. H. J. E. Peake.

To carry out research among the Ainu of Japan.—Prof. C. G. Seligman, F.R.S. (*Chairman*), Mrs. C. G. Seligman (*Secretary*), Dr. H. S. Harrison, Capt. T. A. Joyce, O.B.E., Rt. Hon. Lord Raglan.

To conduct archæological and ethnological researches in Crete.—Prof. J. L. Myres, O.B.E. (*Chairman*), Dr. G. M. Morant (*Secretary*), Dr. W. L. H. Duckworth.

To report to the Sectional Committee on the question of re-editing 'Notes and Queries in Anthropology.'—Prof. H. J. Fleure, F.R.S. (*Chairman*), Mr. Elwyn Davies (*Secretary*), Prof. J. H. Hutton, C.I.E., Dr. G. M. Morant, Prof. A. R. Radcliffe-Brown, Prof. C. G. Seligman, F.R.S., Mrs. C. G. Seligman.

SECTION I.—PHYSIOLOGY.

To deal with the use of a stereotactic instrument.— (*Chairman*), Prof. R. J. S. McDowall (*Secretary*).

SECTION J.—PSYCHOLOGY.

The nature of perseveration and its testing.—Prof. F. Aveling (*Chairman*), Dr. W. Stephenson (*Secretary*), Prof. F. C. Bartlett, F.R.S., Dr. Mary Collins, Prof. J. Drever, Mr. E. Farmer, Prof. C. Spearman, F.R.S., Dr. P. E. Vernon. **£5.**

SECTION K.—BOTANY.

To formulate and report upon a scheme to found a national collection of type cultures of Algae and Protozoa.—Prof. F. E. Fritsch, F.R.S. (*Chairman*), Dr. Muriel Robertson (*Secretary*), Prof. D. Keilin, F.R.S., Dr. Doris Mackinnon, Dr. W. H. Pearsall. **£25.**

Transplant experiments.—Sir Arthur Hill, K.C.M.G., F.R.S. (*Chairman*), Dr. W. B. Turrill (*Secretary*), Prof. F. W. Oliver, F.R.S., Prof. E. J. Salisbury, F.R.S., Prof. A. G. Tansley, F.R.S. **£5.**

SECTION L.—EDUCATION.

To consider and report on the gaps in the informative content of education, with special reference to the curriculums of schools.—Sir Richard Gregory, Bart., F.R.S. (*Chairman*), Mr. A. E. Henshall (*Secretary*), Prof. C. M. Attlee, Mr. G. D. Dunkerley, Miss L. Higson, Mr. D. Shillan, Dr. F. H. Spencer, Mr. H. G. Wells.

To consider and report on the facilities for the education of those who enter or are engaged in industry, with special reference to the needs of (1) manual, and (2) non-manual workers.—Dr. A. P. M. Fleming, C.B.E. (*Chairman*), Mr. A. Gray Jones (*Secretary*), Miss L. Grier, Mr. Lester Smith.

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THE ADVANCEMENT OF SCIENCE

VOL. I. No. 3 APRIL, 1940

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NOTE ON COMMUNICATIONS TO THE SECTIONS

DUNDEE MEETING, AUGUST 30–SEPTEMBER 1

When the Dundee Meeting was brought to a close after three days, it was decided that all communications of which the delivery was unavoidably cancelled should be taken as read. Abstracts (or titles) of communications are therefore printed in these pages whether the communications were delivered or not, and references to dates and hours, as furnished in the Journal issued at the Meeting, are excluded.

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It is intended to supply an index to the four parts in each year, in the July issue.

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THE ADVANCEMENT OF SCIENCE

NOTES

In the preceding issue of The Advancement of Science it was stated that the General Committee had instructed the General Officers to arrange a short Conference at a suitable place, in lieu of the appointed Annual Meeting in the present year. It is now possible to announce that, subject to unforeseen circumstances, a Conference will be held by the Association in the University of Reading, by kind permission of the Council of the University, from Thursday, July 25, to Saturday, July 27, under the Chairmanship of Sir Richard Gregory, Bt., F.R.S., President of the Association. It is contemplated that the Conference should last for an afternoon, a full day, and a morning. It is called a Conference to distinguish it from the usual Annual Meeting. The Conference, in general terms, will deal with Science in National and International Aspects.

It is not contemplated that the usual Sections should meet individually unless reason should emerge for any of them to do so ; nor is it intended to make the usual appointment of new sectional officers.

It is proposed that after a short opening general session the Conference should divide into groups sitting concurrently. For such groups, four general headings have been formulated :—

(1) International Intellectual Co-operation.
(2) Natural Resources and National Needs : (*a*) Minerals, (*b*) Plant Products.
(3) Social Aspects of Human Nutrition. (Not necessarily confined to this country).
(4) Scientific Discovery and Progressive Industry.

The first and third of these subjects would have been dealt with by the Division for the Social and International Relations of Science at the Dundee

Meeting last September if that meeting had not been brought to a premature close.

These groups together cover a wide field, and communications in various departments of science will find places in one or other of them ; but communications appropriate to the Conference, though outside the range of the groups, may also be included.

Full particulars of the Conference and arrangements in connection therewith will be issued in due course.

The small permanent office staff of the Association has been reduced by the withdrawal of the assistant secretary, Mr. D. N. Lowe, for service in the Ministry of Supply, and of Mr. A. J. Faulkner, assistant clerk, in order to join the N.A.A.F.I.

* * *

The present issue of THE ADVANCEMENT OF SCIENCE is necessarily reduced in bulk in comparison with Nos. 1 and 2, owing to the rationing of paper, as well as to financial considerations. It had been intended to complete the publication of material relating to the Dundee Meeting in this issue ; but it has now been found necessary, and on other grounds desirable, to hold over to No. 4, the July issue, the transactions of Section L (Education), which, in addition to Dr. A. P. M. Fleming's presidential address and abstracts of communications, will include the important reports of the committees on Educational Research and on the Informative Content of the School Curriculum. It is hoped also to publish in the next issue the British and American Association Lecture, which should have been delivered at the Dundee Meeting by Dr. Isaiah Bowman, president of Johns Hopkins University, U.S.A., on Science and Social Pioneering. This would have been the first lecture under the arrangement concluded in 1938 between the British and the American Associations for the Advancement of Science, by which, in alternate years, an American speaker should address the British Association, and a British speaker the American Association.

The grounds of Down House, Darwin's home at Downe, Kent, which is preserved by the Association as a national memorial under the gift of Sir Buckston Browne, F.R.C.S., were reopened to the public from Good Friday last, between 10 A.M. and 6 P.M. The Darwin memorial rooms in the house remain closed to public access.

RATES AND TAXES

ADDRESS TO SECTION F.—ECONOMICS

By Prof. H. O. MEREDITH

PRESIDENT OF THE SECTION.

In searching for a subject upon which I might venture to address you I was attracted to public finance by a number of considerations. Of these the most important were: first, that we meet here issues which in a high degree are controllable at will; within limits we can decide, both what proportion of the national dividend shall be appropriated and spent by public authority, and how the total contribution shall be subdivided between individuals. Secondly, having this power of choice we have also a serious responsibility for its exercise: there is no such thing as a neutral financial policy; we are bound to do this or that, and the implications of this differ from the implications of that in terms of soul and body. Thirdly, it would seem that action in this field is not wholly beyond the reach of argument: passion, no doubt, counts for much; conservatism for more; idleness, hurry, inconsequence for most; but financial authority does sometimes betray discomfort when confronted by reasoning which it is incompetent to answer; exceptionally we may even encounter a 'poor fish' like Peel, who crumpled up his notes while Cobden was speaking and muttered to a colleague that someone else must reply. Lastly and more dubiously, I thought that I myself had something to say on this topic, little as I might relish the prospect of saying it.

Let us begin by reminding ourselves that the main drift of social and economic evolution seems to portend a persistent increase in the ratio of public to private expenditure. If we are to continue to fight and to prepare for fighting, that goes, almost, without saying. It would, however, probably occur even if we found a way out of war; indeed, it might well be a necessary factor in the discovery of a way. It seems, in a word, certain that a larger and larger proportion of man's energy will be expended, as time goes on, in ways and for purposes whose cost cannot be financed by the sale of discrete *quanta* to individuals and must therefore be covered by more or less voluntary contribution. Purely voluntary systems of association can, it is true, do something in these fields; in the past that something has been much. But the broad teaching of experience in this matter shows that voluntary association is useful chiefly at the stage of initial experiment and in relatively minor undertakings. When it comes to mass-education, mass-insurance, mass-provision for recreation, drainage, or what not, the element of compulsion is as unavoidable as in the case of mass-war.[1]

[1] It is sometimes supposed, and superficially the view is not unplausible, that much of this tendency is a corollary to income inequality, and that the movement would weaken

Next it is to be remembered that this persistent increase in the ratio of public to private expenditure implies in two ways a parallel increase in the importance of determining the distribution of taxation throughout the community accurately and in accordance with principle. In the first place an appreciable part of the *raison d'être* of the process is the need to modify the allocation of income which results from contract, ownership, and inheritance. It is universally agreed that part of our financial objective is to reduce in some measure the discrepancy of real income between rich and poor. How far we want to go in this matter is, of course, disputed and must probably always be disputable, but to the extent to which this purpose is admitted its logic must condemn any element in our system which opposes it and be critical of any element which in regard to it is random or uncertain in its action. And secondly, the mere increase in the proportion of income arrogated to public purposes enhances disproportionately the evils of random taxation. When I am only asked for two per cent. of my income it matters little if, from the point of view of either equity or economy, that two per cent. ought to have been one. There will, on the other hand, be an enormously important difference if, when my proper contribution is twenty-five per cent. of my income, I am asked to pay fifty.

If we approach our actual practice with these considerations in mind, the examination of a representative budget statement and debate becomes a somewhat alarming and deeply humiliating experience. It is evident always, in the first place, that all parties concerned are definitely *frightened* of taxation. One can almost *hear* the sigh of relief when in an hour of alleged and apparent national emergency it is found possible to evade an addition of threepence to the income tax. The whole language of financial discussion is suffused with the feeling that taxation is a bad thing, and not only a bad thing but one which we do well to run away from. Secondly, we may note always a lamentable incuriosity both as to where, broadly speaking, the burden of taxation (if it be a burden) rests and what its effects are, together with an impatience of any endeavour to probe into these questions. There are, it is true, certain venerable traditions to which appeal is made with all due solemnity—and brevity. It is an axiom, apparently, that both direct and indirect taxation should 'bear their share,' but no considered discussion takes place as to what these shares ought to be. It is again an axiom that taxation in general, and the income tax in particular, are 'bad for trade.' At this point, also, no undue cackle is tolerated ; our governors are too anxious to come to their horses—to discover as quickly as possible with just how little alteration of the existing system the situation may be tided over for one more year. Briefly, the characteristic note of budget-discussion is a certain glum frivolity. There is an evident, and to do our House of Commons justice a *curious*, lack, in this particular field, of the intellectual and moral courage which in other quarters it displays.

greatly if incomes were equalised. It is, I think, evident that if incomes were equalised by a return to more individual methods of production and tenure of property, the functions and cost of government would be alike restricted. If, however, the goal were approached without abandonment of collective and co-operative technique, I should anticipate the converse. The smaller the range of inter-class standards of living the more easy would it become to discover objects to which that technique could be applied, and the less would be the obstructive force of disparate aims and interests.

A central difficulty is, undoubtedly, that although we have adopted many of the forms of democracy, citizenship retains in regard to taxation something of the sentiment which belongs to servile status, while government has not quite discarded the mental habit of predaceous authority. Our representative citizen does not enjoy paying taxes; if opportunity of evasion within the law presents itself he avails himself thereof; if it does not present itself he will hire specialised ability to discover it; finally, he is none too scrupulous in seizing opportunities which are definitely beyond the law. Unquestionably this distaste for taxation goes far to explain, and even in some sort excuses, the miserable figure which our financial system cuts: every Chancellor of the Exchequer knows that the feeling of the House will be with him in every argument evasive of immediate increase in expenditure or taxation. To what are we to ascribe this recalcitrant temper? It is convenient to distinguish three strains in its genesis. First and most obvious is the fact that the modern State still is appreciably predatory, the representative citizen still does occupy a quasi-servile position. This is an evil which can be cured, if at all, only with time and by persistent effort. I shall remark, however, that in so far as it exists it seems specially important to make financial principle explicit, to show the representative citizen what he is doing in this matter to others or others to him. Only one tentative movement has been made in this direction during my lifetime, namely, the official estimate some ten years back of the weight of taxation at different points in the income scale. This calculation showed, it will be remembered, that our taxes are regressive on the lowest incomes, a necessary consequence of attacking those incomes by indirect taxation. A further and more important element of regression is involved in our local rates taxation, and in the compulsory contributions to health and unemployment insurance. The official enquiry raised, perhaps, more questions than it answered, but why has the matter been dropped? Why is not every budget statement accompanied by a memorandum explaining broadly the relation of the taxes proposed to the national totals of wealth and income and the ratio of taxation to income at different points in the income scale?

Secondly, there is the inevitable limiting factor of individual defect. It is not easy for a man to face his civic obligations as honestly as he faces his butcher's bills, because in the nature of the case he cannot see them as clearly. Men cheat the Government, much as they cheat a railway company, not only because they dislike or fear it, but simply because it and its doings are beyond their power of comprehension and sympathy: their relations with it are too amorphous, too indirect, too indistinct. This factor, also, is controllable, if at all, only with time and by deliberate effort. To create the sense of citizenship where the concept is non-existent is the master problem of statesmanship. In this case also, however, it would seem that one method of progress would be to confront the representative citizen with fuller and clearer statements of what financial policy is and what it implies in relation to his own income and the incomes of other people.

There is, however, I would suggest, a third by no means unimportant strain in our dislike of taxation which may be more amenable to argument, namely, the tradition that public expenditure is costly in some further and fuller sense than are private disbursements. The existence of this feeling is unquestionable. All debate in Parliament, all discussion in the press, is suffused

with suggestion of that ancient fallacy, the distinction between productive and unproductive labour, and its corollary that the incomes of those who are employed by the State are derivative from the product of industry. Seldom do we encounter the clear-cut view that activities of government co-operate on an equal footing, to say the least, with activities of private enterprise in generating the national dividend. Everywhere we can trace remnants of the ghastly Gladstonian doctrine that money should be left, where possible, to 'fructify in the pockets of the people.' Other things being equal, of course it should : yet equally should it be brought, where possible, to fructify in the coffers of the State. Actually, money will not fructify if it is left either in pockets or in coffers ; it will merely weight the swimmer down or sink the ship. Gladstone expressed his meaning with customary clumsiness and inaccuracy. What he really had in mind was money springing nimbly from pocket to pocket, promoting prosperity by its leaps and bounds. It may, however, travel no less nimbly when it has been expended by the State.

Victorian finance, with all its obvious defects of imagination and emotion, had the sovereign virtue of logical cohesion. Granted the major premise of *laissez faire*, that the State is only necessary for the restraint of evil conduct at home and ill-will abroad, a decision to reduce taxation to a minimum and to raise that minimum by duties on stimulants and sedatives has much to commend it. For if the less government the better, then obviously also the less public expenditure the better : *ergo* minimise taxation. And if such government and taxation as are required are rendered necessary by vice : why should the virtuous citizen contribute anything ? May he not reasonably argue that if all men were as he is there would be no need for even the minimum of government and taxes ? Is it not reasonable, then, to raise revenue exclusively by duties on forms of consumption which are vicious or allied to vice, like the smoking of tobacco and the drinking of alcohol or tea ? If, lastly, it be objected that the virtuous should at least contribute to defence against external ill-will, it may be answered that it is the vicious in all countries who occasion war and preparation for war, and that justice will be done on balance if all countries raise their revenues exclusively from the less virtuous of their citizens.

These arguments have never, perhaps, been advanced deliberately and in their full enormity by any responsible person : on the other hand, not very many of us succeed in avoiding them altogether. Indeed, it may be well to consider, before going further, whether there is not so much of sense in them as might justify us in retaining them not indeed as the basis of our system of taxation but as an auxiliary support ; for the feeling is common enough in men of all classes that the State owes more to them than they to it, and that, therefore, anyone rather than themselves ought to contribute to its expenditure. This attitude I have noted more particularly in elderly bachelors and spinsters and in widows of moderate means, who are comfortably off but inadequately occupied or interested. It is evidently in such cases as theirs that it is most nearly defensible, for it is these individuals, in general, who have obtained least satisfaction from lives indisputably virtuous. Nevertheless, it must be insisted, relief from taxation is not the right remedy in this and in analogous cases. In so far as their grievances are material tax relief would be in its total inadequate, in its subdivision indiscriminate ; in so far as they are spiritual, pecuniary compensation is inappropriate. The same dilemma may

be pressed, I believe, more broadly, against all those who believe that their virtue entitles them to evade taxation. We must ask them to take more seriously the view, so often enunciated, that virtue ought to be its own reward, as also the less popular corollary that vice should be its own penalty. We should remind ourselves, further, of the enormous *practical* wisdom which is enshrined in those esoteric doctrines : all actual estimates of virtue and vice must always be too largely subjective to furnish in a democratic community a satisfactory scheme for the distribution of taxation.

Victorian finance in England was, we have suggested, a logical outgrowth from the doctrine of *laissez faire*. Our trouble is that while abandoning that doctrine we have never seriously set ourselves to think out financial principles comparable in their logical cogency with those which guided Gladstone. Our tradition retains, no doubt, some valuable legacies from the past, notably a certain sobriety in experiment and a rugged exactitude of accounting : these virtues, however, in so far as they are virtuous, are formal ; they nowhere touch the essence of the matter ; it is as though we had no sense either of where we want to go or of how to get there, but merely certain rules of the road and a speed limit. One result of this atrophy of living principle is that whereas the Victorians were capable upon occasion of really large measures of reconstruction in advance of the pressure of necessity, our finance seems more and more to make that fatal error of strategy—conforming to the enemy ; instead of grasping nettles we wait until we are stung. It is true, no doubt, that the Victorians were concerned primarily with retrenchment, and that it is always easier to scrap than to build, yet it will probably be conceded that we are, in financial policy, increasingly passive and show ourselves less and less capable of vigorous initiative. Alterations in our tax system become more and more a matter of yielding to pressure rather than of constructive planning : it follows incidentally that where that system bears with undue hardship on individuals a large measure of oppression must occur before any relief is accorded ; and further, that what relief is granted more frequently resembles a sop to Cerberus than an orderly rationing of food. The troubled conviction that something has got to be done which issues from an atmosphere of desultory grousing is apt to generate measures which combine a minimum of relief at points where it is really needed with a maximum of expense to the State. Let us illustrate these remarks by considering two cases : first, that of the income-tax allowance in respect of children, secondly, that of de-rating.

The initial relief in respect of a child exempted £10 from income taxation at a time when the tax stood at 9*d.* in the pound on earned incomes. I do not remember to have seen it remarked at the time that this worked out at 7*s.* 6*d.* per child per annum, the very figure which was at the same time in England the cost of a dog licence. We have advanced since that date to £60 per child, which, with tax at 5*s.* 6*d.*, yields the princely sum of £16 10*s.* per annum, approximately 6*s.* 4*d.* per week for income subject to the full rate of 5*s.* 6*d.* in the £, but of £5 only (2*s.* per week) for income subject to the 1*s.* 8*d.* rate. Allowance being made for rise in the standard of child welfare since the war these figures are divertingly reminiscent of Mulvaney's taunt to his sergeant : ' squawlin' on a counterpane at half-a-crown a week.'

What was the *raison d'être* of this curious gesture to parents ? Presumably it was a concession to a vague feeling that something should be done to ease

the expenses of those who rear children. But is such easement required, and, if so, in what circumstances and to what degree? We must suppose it to be assumed by those who have been responsible for these measures that a married couple with children is at any grade of income worse off than a married couple without children. If we take the extreme case of a family with six or more children this is evident. The income which implies plenty for two may infer penury for eight. If we take, on the other hand, the minimal family of three it is by no means obvious. Very little knowledge of actual life is needed to stir the suspicion that average humanity gets more satisfaction from what it spends upon a single child than it could derive in the absence of the child from spending the same sum in other ways. We might, in fact, develop a case for charging childless couples somewhat less than their more fortunate fellows, and might even extend this argument to two, conceivably to three children, without becoming palpably absurd. Few couples, we suspect, deliberately limit their offspring to less than two if they are willing to procreate at all, and it is certainly not the income tax allowance which prevents their halting at one: its ratio to the cost of a child is obviously far too small to affect the decision in the vast majority of cases. What this boils down to is that through obeying the vague sentiment that something ought to be done, without seriously considering what we are about, we have drifted into the absurd position of wasting on small families (the vast majority of cases are small) sums of money far more than sufficient to give ample relief to large families, while according to our small number of large families a relief which is ludicrously inadequate to its presumable purpose. There was even a time when the relief on a first child was greater than the relief on a second or third. That crowning absurdity has been removed, but the fundamental stupidity of the whole scheme remains unaltered.

Let us consider next another feature of the scheme, namely, that it makes, after the first few hundreds have been passed, no differentiation in the amount of relief at different scales of income. If it be admitted that the object of the system is to relieve appreciably the family with many children as compared with the family with few, we have here a second absurdity: for a sum which at one level of income would be adequate to this purpose will evidently be inadequate at another. What is the use of presenting £16 to a man who is spending perhaps £150 per child if your object is to promote larger families in the upper half of the income scale: families of four to six in place of families of one to three children? It is a pill to cure an earthquake. Can any sane person believe in such nonsense? It is the perfect parallel to our practice of fining individuals without regard to their incomes, so that a given offence may send a poor man to prison for a month whilst a rich man escapes at something less than the cost of an evening frittered in town.

We turn now to de-rating. And here we must beware of taking surface absurdities at their face value, and supposing that no serious reason can exist for policies fallaciously defended. The popular case for de-rating rested on appeal to the naïve misconception that agriculture, industry and transport are more productive than commercial and professional services, entertainment, and housing. This factor was re-enforced by a sense of the temporary embarrassment of our staple industries and the chronic difficulties of agriculture. Viewed whether as temporary relief or as a permanent subsidy the procedure was partly too indiscriminate, partly inadequate. Viewed as a semi-authorita-

tive endorsement of the notion of higher productivity the policy should make us blush. It had, however, an esoteric justification which deserves consideration. The central problem of local finance is to devise suitable forms of local taxation, to attack in each locality those incomes which may properly be drawn upon to defray the special requirements of that locality. The difficulty of this problem hinges, in turn, upon the fact that there are *no* incomes (in a modern state) which are wholly and solely local in the relevant sense. It is a question therefore of choosing between sources of revenue which are adequately and those which are inadequately local. Now it does seem broadly true that the incomes implicated in rating of agriculture, industry and transport are in the modern world increasingly non-local. The fact that a given agricultural area has through proximity to London high productive power in dairying or the growing of fruit and vegetables gives London rather than the area a claim to its taxation. Mines, factories and railways are even more evidently unsuited to local taxation. And, on the other hand, the bulk of housing and of retail trade and entertainment, together with a large proportion of wholesale trade and professional services, are as evidently local in their main implications. We might accordingly defend the de-rating scheme esoterically, as a decision to extrude from our system of local taxation elements obviously unsuitable to it whilst at the same time increasing the proportion of central government grants for local purposes in accordance with the ever-growing integration of local and national life.

Are we then in contact with one of those cases, so familiar to students of Economics, in which approximately the right course has been taken for approximately the least valid reasons? It is impossible, unfortunately, to maintain this optimistic view. So long as concrete capital and land are taxed at all, there are grave objections to exempting any part of them from taxation. On the one hand de-rating must encourage transfer of investment from those forms of property which continue to be rated with presumptive loss to the national dividend. And on the other hand, whether we consider the beneficial or the onerous aspect of public expenditure the de-rated properties, taking the community as a whole, obtain benefits for which they should pay, and impose costs to which they should contribute. It is accordingly evident that so long as local rates are continued on other forms of capital, properties de-rated locally should pay a consolidated national rate into a national pool.

If we turn now to consider, broadly, what if any part of our financial system can be approved in principle and seems to be suitable for development, I suggest with some confidence that our main direct taxes, income-tax, sur-tax, and death duties, are our only unassailable sources of revenue. Not, of course, that any or all of them stands beyond criticism: each of them may be blamed on points of detail. There is, however, I should maintain, a sufficient *communis opinio* that they are all desirable and (what is at least as important) all of them can be defended by serious arguments. Income *is* in fact the best rough measure of capacity to bear taxation; capacity to bear taxation *is* proportionately greater with a large income than with a small. These axioms give us a valid basis for progressive income-tax and sur-tax. And again, those who inherit can usually bear taxation, *pro tanto*, more easily than those who do not inherit, while there are weighty reasons for limiting the

tendency of hereditable wealth to increase the inequality of distribution. The most serious objection that has been urged in the past against all these taxes is their alleged tendency to inhibit accumulation. This objection seems never to have been really cogent during the past century and a half. To-day it is no longer even plausible in view of the tendency for desire to save to outstrip the possibilities of advantageous investment.

The axioms which are generally accepted as validating these taxes create however, at once, an initial presumption against our other main sources of revenue, the indirect taxes on commodities and the local rates. For these taxes are admittedly, when looked at from the point of view of income, regressive in a high degree. They have, further, no appreciable relation to windfall or unearned increments of wealth, and they intensify rather than diminish inequality. There are, of course, elements in each of them of a different character. Customs and Excise duties are taxes not on all income expenditure but on certain modes of consumption which are for various reasons alleged to be, relatively speaking, unnecessary, deleterious, or noxious. Local rates again do not, in all probability, fall wholly upon purchasers of goods or services derived from rated property and the inhabitants of rated dwellings. In part they intercept income which would otherwise pass *via* land values to hardly traceable recipients ; they may also conceivably take some small toll of interest. Finally, taxes on commodities have long been defended as the only possible way of reaching certain incomes which ought to be taxed and which, it is alleged, cannot be reached effectively by direct taxation. Rates are analogously commended as the least bad way of financing local autonomy. We have then to examine what weight may reasonably be assigned to these considerations.

The taxation of commodities was not perhaps always so ridiculous as it appears to be to-day. So long as trade was a mere excrescence or fringe upon a predominantly local productive system there was some sense in adding to the cost of commodities which the King's peace enabled to be transported a part of the cost of maintaining that peace. Again, when consumption was largely standardised for each class and graded from one class to another it may have been possible by suitably adjusted taxes to achieve approximately a progressive taxation of income. In the eighteenth century, for instance, it is not wholly impossible that taxes on tea, alcoholic beverages, silks, lace, armorial bearings, windows, and men-servants operated partly, in this way, It is indeed to be doubted whether the whole system of commodity taxation could ever have been justified on these lines after the sixteenth century. The main force behind it in the last three centuries has been, almost unquestionably, the desire of the well-to-do classes to detax wealth or minimise its taxation. It is characteristic of the difference in national temper between England and France that whereas in France the aristocracy asserted a privilege of exemption from direct taxation, in England property was content to establish and exercise a constitutional right of exempting itself. An intuition that there ought to be no direct taxes gathered force throughout the sixteenth and seventeenth centuries. In the eighteenth century we piled up debt rather than face taxation until the mounting total of interest put Government to the choice between *seisachtheia* and a proportional income tax. The income tax was abolished as soon as Napoleon had been settled with, and though re-imposed

by Peel its right to existence was questioned by so representative a man as Gladstone as late as the 'seventies. There was, indeed, as some of us can still remember, no serious taxation of income until we were well into the years of the Great War, whilst Harcourt's death duties, so marvellous at the time, create in retrospect the wonder that they were delayed so long and were so insignificant.

These historical considerations should, I think, induce caution in accepting at face value any of the traditional arguments in defence of our taxes on commodities. We should remind ourselves that at the time when they were formulated the governing class had a sinister interest in believing them. We should remind ourselves further of the extent to which they have been buttressed at some important points by puritan fanaticism. Let us turn for a moment to consider the argument which represents the duties on tobacco and drink as an admirable, if not necessary, method of regulating undesirable consumption. In my own case, and I speak with forty years' experience of nicotine-excess, the heavy taxation of tobacco has effected just nothing. I do not smoke one cigarette or pipeful the less because with every puff I contribute to the revenue. What is true of myself seems further to hold, broadly, throughout society. Both men and women appear to smoke more and more as time goes on and the taxes on tobacco rise.

Drinking, on the other hand, and more particularly moderate drinking at meals, has unquestionably declined. There are, however, other reasons for this, and the extent of excessive drinking is still notable in all ranks of society. Briefly it is evident that as a method of limiting undesirable consumption taxation is a 'wash-out.' Its effect is to penalise, not to restrain. If there were any serious intention to promote temperance by control it must operate by attempts to improve the quality and environment of consumption, and probably also by rationing. It may even be doubted whether the taxes would be kept as high as they are, still more whether they would ever have become so high, had elasticity of demand (the index of the restrictive effect of taxation) been adequate to reduce their yield. The pea would then be shifted to another thimble ; we should hear less of the moralising value of these taxes and more of their importance as revenue producers.

The argument from morality is, it should be conceded, more of a force in reserve for the support of these taxes than their first or even second line of trenches in actual debate. The main argument is that they bring money in, and while admittedly inequitable are not much felt, roughly what one hears a man say when he has evaded the income tax or swindled a railway company. That they bring in money is beyond denial, but what, if any, truth is there in this doctrine that they are 'not felt'? If in fact we smoked or drank appreciably less because of them, or if our women wore less silk, there might be something in it. In so far as the delight of luxury expenditure is dependent upon distinction, then, if everyone scales it down in proportion, the delight continues unabated. It is true, of course, that the search for objects of universal or even general luxury consumption has become illusory : we gratify our taste for luxury in too differentiated a fashion. But, waiving this point, in so far as demand for these things is inelastic, the taxing of them *does* impose a burden, it restricts our consumption of other things. We must not now at this point shift the pea under yet a third thimble by pontificating that 'of course'

taxation is onerous. If a burden is imposed these taxes are condemned by their inequitable distribution of that burden. Let us notice also, at this point, their occasional tendency to penalise some of the least happily circumstanced members of society. It is an unpleasing thought that the family of a whisky addict may have to choose between his contributing ten or twelve shillings a week to taxation at the expense of their food and firing, or turning to some cheap substitute such as methylated spirit or coal-gas bubbled through milk. Doubtless women ought to select their husbands more wisely, and children their fathers with even closer prevision, yet when all due care has been taken mistakes must still be made.

What holds in the extreme of drink and tobacco seems to hold generally of all taxes on commodities. We cannot regard them otherwise than as an excessively inequitable and random method of raising revenue. But what of the argument for them as the only available method of levy on a class which ought to contribute? This was the contention, if I remember right, to which Marshall attached importance, though he was always careful to add that whatever we took by taxation from the poorer classes should be returned and more than returned in beneficial State service to them. I feel that this argument is exceedingly relative to place and time together with the parallel reasoning in favour of a general customs tariff as a financial resource in communities where for one reason or another direct income taxation may be unworkable. So far as our own place and time are concerned, I rate its force as negligibly small. The technique of income taxation needs improvement, but it has improved and is improving, while the whole drift of social evolution is persistently reducing the fraction of national income which cannot be attacked directly. So far for the contention that members of the middle and upper classes who evade direct taxation are caught by duties on silk or wines or whisky. As regards the wage-earning class, the plausibility of the argument was weakened irreparably thirty years ago by that ingenious device for taxing wages regressively—the stamped card. It is true, no doubt, that despite all extensions there are still a number of small incomes which escape that net and that the final step of linking it up with income taxation has yet to be taken. In principle, however, the situation is sufficiently clear. It is abundantly proved that direct imposts upon the poorest of the poor are by no means administratively impossible.

Turning now to the local rates, it hardly needs argument to convince us of their pernicious tendency in so far as they do not fall upon the value of land. The heaviest contributions to them come now from the prices of goods sold at retail and the rents paid for dwellings, and at least the second of these elements is in a high degree regressive as between grades of income and appallingly oppressive at each grade of income to the larger as compared with the smaller family. The taxation of dwellings is perhaps upon the whole the most evil tax in principle which has ever been invented; it attacks a necessary of life the demand for which is elastic. It is unpleasant to think that some five or ten per cent. of a minimal income may often be exacted by this device. As against this we have to weigh the considerations that rates are a method of raising local revenue and that some substantial part of their incidence rests in all probability upon beneficiaries of land value. On the first point we see no valid argument, granted that income taxation were suitably extended, against

utilising it for local as well as for central purposes. It would, of course, be necessary to develop specific doctrines of local attachment for individuals and of the proportions of their incomes properly liable to local income-taxation. To do this satisfactorily and with acceptance would certainly not be easy, but it is precisely my case here as elsewhere that the difficulties of rational taxation ought to be faced ; that we can no longer afford to turn our backs upon them and let things drift. It is vastly important to educate ourselves in economics and I can imagine few more fruitful methods than that of inducing serious popular discussion of the questions—who ought to contribute to local expenditure, for what reasons, and in what amounts ?

The land value and capital aspect of the matter is more difficult, and, since an analogous problem would present itself if taxation of commodities were abandoned, I must aim at some statement which will, in outline, cover both cases. One reason why many solid minds will refuse to recognise what seem to me the palpable wickedness and folly of these taxes is the enormous difficulty of devising a retreat from them which will not involve, in the short period at least, substantial windfall gains to certain individuals. Repeal of rates might in theory be accompanied by the introduction of a special tax on land values, which would absorb about as much land value income as the rates in fact intercept, but I confess to doubts of the practical wisdom of any such attempt. It is more difficult to conceive even in theory of any satisfactory way of preventing considerable benefit to owners of rated buildings if the rates were abolished, and to special industries and interests if commodity taxation were abandoned. Possibly in the case of the larger firms in the drink and tobacco industries some special taxation of surplus profit might be reasonable over a limited period. In the main, I admit to feeling on this side of the matter that a price has to be paid for escape from a faulty policy ; after all the price is for a limited period : the evils of the faulty policy, if it is persisted in, are permanent and cumulative.

It would be interesting to pursue in detail the minor absurdities of our stamp duties, the ineptitude of N.D.C., the inconsequence and monstrosities of our dealings with entertainments, petrol, and motor-transport, but my time and your patience are alike approaching exhaustion, and I shall prefer to attempt some rounding off of the main ideas which have underlain my paper. It will, I hope, have been evident that in suggesting abandonment of rates and indirect taxes and reliance upon a generalised system of progressive income taxation and taxes on inherited wealth, I have been actuated by political at least as much as by economic considerations and by a feeling for what I will venture to call civic virtue more than by anything else. I believe in direct taxation not merely because I see in it the only potentially equitable system and therefore (partly) the only truly productive system in the long run, but also because I see in it enormous possibilities of interesting the citizen in the State, in his relation to it, in what he gets out of it and what he gives to it. I confess to some impatience of the argument that indirect taxes should be credited with a merit in not being felt, holding strongly on the contrary that we ought to feel our taxes, that we are far more likely to value what we know we are paying for than what we suppose we are 'scrounging.' Is there not, in reality, a definite satisfaction in meeting one's bills which ought not to be denied to the citizen of a democratic state ? I want, in fact, to suggest

that whatever arguments of technical expedience or practical convenience may urge us to get the money in without worrying unduly about where it comes from, this is a kind of conduct which no wholesome person tolerates for a moment in his own case, and that the State in this as in other matters should set an example above rather than below the level of its average citizen. By clinging tenaciously to methods which may have been appropriate or inevitable in past centuries we are forfeiting the encouragement to and enlightenment of good citizenship which might be achieved if our financial principles were more clearly defined and more sanely defensible economically and morally than they actually are.

It is part of my thought on the matter, and I wish to make this clear, that our direct taxes need a good deal more refinement and elaboration to suit them to our needs. We must be prepared to go a good deal further in adapting them to differences of individual circumstance than we have in the past. In particular there is required, in my opinion, far more adjustment to the number of persons whom a given income in fact maintains, a far more liberal treatment of widows and invalids dependent upon small incomes from property, more consideration of the difference between the man who enjoys a large income for many years in succession and one who earns it only once or twice in a lifetime. Another large field for enquiry is offered by the problem of variable profit. As we abandoned the income tax after Waterloo, so we scrapped after the Great War the excess profits duty. Some attempt at further experiment in that field seems to have underlain the initial plan for N.D.C. Sooner or later, if private enterprise survives, there must be development on this side. There are again a number of obvious problems awaiting attention in the taxing of inheritance. None of all these urgent matters are likely to be seriously attended to unless we can break with that traditional attitude towards finance which I have ventured to depict and criticise, and partly for that reason I have restricted myself to generalities in presenting my case.

There remains for consideration one final legacy from the age of *laissez faire*: namely, the famous canon of exempting from taxation the minimum necessary to subsistence. I suspect that the ghost of this canon lurks somewhere behind our curious procedure in regard to the allowance on account of children. Possibly £10 was thirty years ago the officially accepted minimum of subsistence for an income-tax baby and for aught I know £60 may be to-day. 'Ghost,' advisedly, since there never has been a time at which taxation failed to nip at least nose and fingers of the ultra-poor. However this may be, it is very much in my mind first that this canon though logical enough under *laissez faire* has no claim to be accepted to-day; and secondly that it is living on in our altered state and playing a part in that, to me, curious idea of many people that nothing appreciable is really due to the State until one has passed, say, the £3 a week line for an individual or the £300 a year line for a married couple with two children. My feeling is, on the contrary, that a contribution sufficiently heavy to be 'felt' should be called for from the very bottom of the scale. In this matter I am wholly on the side of those German economists who insisted throughout the nineteenth century that something was due to the State from the very poorest, and I would suggest most seriously that the willingness to bear taxation cheerfully, which is evident in Germany, and which puts us here to shame, is a noteworthy

symptom of essential vigour and value in the life of a nation.[2] I have, then, no patience at all with the typical bourgeois socialist who considers that the modest £500 which represents to him a minimum standard of cultural existence ought to be sacred so long as any individual is allowed to spend up to £20,000 a year. I will go far with him in promoting such changes in our institutions as will make enormous incomes impossible. But I should feel more comfortable if I could persuade him, pending those changes, to accept my own thesis, that honour compels the citizen, even of a faulty community, to make a sensible sacrifice towards its upkeep. I use deliberately the word ' honour ' rather than the word ' equity.' If it is a question of what is ' fair ' it seems clear that the contribution made by our working and lower middle classes, both in their productive labour and in their expenditures on rearing children, so grossly exceeds what is due from them as compared with what is due from the wealthier classes as to justify a claim that incomes below £300 per annum should pay no taxes at all. But everyone who is worth anything knows in his bones that the attempt to base human association upon equity only is doomed to failure. If individual soldiers insisted to the limit that it was unfair for them to be killed, if women insisted that it was unfair for them to suffer and die in child-bed, if everyone everywhere stood strictly upon his rights, no one would get anything. We need to qualify, and we do in practice, all of us, qualify, the claim for our rights with the assertion of our honour, and I am convinced that it is psychologically essential, if we desire to build a democracy, to enshrine this principle in our financial institutions. Of all the ideas which we have inherited from *laissez faire* finance the most dangerous for us to continue (granted that we are abandoning *laissez faire*) are the notion of the exempted minimum, and the notion that indirect taxes are desirable because men do not feel that they are paying them. The State ought not to mean so little to anyone as that he will not assert his right to contribute towards it. Still less ought the State to descend to picking pockets. Granted, our State is so imperfect that some of our citizens cannot afford to contribute. We do not *in fact* exempt them : we pick their pockets by rates and indirect taxes. Surely it would be better to put the matter on an open footing, and where we felt shame or met obstruction in collecting from the very poor took measures to make them less poor and in the meantime returned to them in benefits something more than the value of the contributions they made.[3]

[2] Germany enjoys the advantage that her people has never been conquered : in England we still reel from 1066 and all that !

[3] If I am asked *what* benefit could be devised which would really cover all cases, I will answer : a lottery ticket. Not in the ordinary sense of a specific lottery where tickets are sold and the receipts distributed between prizes and tax, but by allocation of say £5,000,000 per annum out of general revenue in prizes and the issue to every man, woman and child in the country of a free ticket for the draw. After all, one of the prime advantages of civilised life is the chance which it gives to the individual of attaining wealth : that chance, however, as things are is appallingly weighted in favour of the middle and upper classes. To him that hath, there is given. Lotteries as a means of raising revenue seem to me only less dirty than taxes on drink or prostitution : they are just one more method of exploiting lightheartedness, extravagance, vice. But a lottery that would *distribute* revenue stands on a different footing. This would bring hope to millions and temptation to none.

SECTION F.—ECONOMICS

COMMUNICATIONS

Dr. M. Bowley.—Housing in Scotland.

The purpose of this paper is to analyse the main differences between Scottish and English housing problems in the post-war period. The housing situations in Scotland and England, respectively, before the Great War are examined briefly in order to bring out the essential features of the problem, and some attempt made to explain the greater seriousness of overcrowding in Scotland than in England. The effects of the cessation of building during the war on the situation in the two countries and the emergence of an artisan and middle-class housing problem are outlined. In the light of this data the achievements of the post-war housing policy are analysed to discover whether the Scottish situation requires treatment different from that of the English.

* * *

Dr. Thomas Adams.—Some economic aspects of urban concentration.

Concentration of industry, economic activities and population in urban centres is essential to secure economic benefits to be derived from scientific progress and need not militate against social welfare. Concentration, however, has become excessive in many urban centres, and has caused intolerable congestion of traffic, impairment of industrial efficiency, and overcrowded building development. It is contended that :

(1) The most powerful force in causing urban concentration is the existence and potentialities for development of transport facilities allied with certain favourable qualities in the natural situation, and the planning and control of these facilities is most essential to prevent excess.

(2) The steady flow and free movement of street traffic is essential for economic efficiency and urban areas need to be planned or replanned to provide the space required.

(3) If the main transport facilities are properly planned and controlled there will be less need to attempt artificial restriction of the location and distribution of industry, and if ample space is provided for purposes of locomotion this space will suffice for essential purposes of air space and recreation.

Economic solutions resolve themselves largely into questions of transport and land prices. The reduction of costs of transport involves the elimination of unnecessary travel ; and the reduction of land prices the elimination of values based on improper or unhealthy uses of land.

More research is needed to ascertain the best methods of reducing ' friction of space ' between producers and consumers of goods and services, and between places of residence and places of work and recreation. Town planning needs to be based more on the data of the economist and less on consideration of sentimental values.

* * *

Mr. A. J. Wensley.—Localisation and concentration of industry.

The general trend towards industrial concentration. The relative growth of the major industrial areas. The central industrial belt.

The industrial composition of the major industrial areas. The location and trend of individual industries. Changes in the location of individual industries and the rate of growth of industries which are relatively static in their location.

Recent developments in the Ministry of Labour Midlands Division. Relative rates of growth of the component areas and of individual industries.

The factors underlying the process of concentration. Cumulative tendencies. The probable future trend in location.

* * *

Mr. A. Collier.—The social economy of crofting districts.

Introductory.—Difficulty of defining a 'crofter'; size of crofting population and districts in which they live; crofter's mode of life and sources of income; township the social unit, individual holdings and common grazing.

Origins of problem.—Break-up of clan system; growth of population consequent on introduction of potato, inoculation, cessation of private warfare, and the kelp boom during the Napoleonic Wars; the coming of sheep and the clearances created by 1820 acute over-population. Emigration, either individual or communal, was forced on the people, but it is remarkable how tenaciously they resisted.

Modern Period, 1875–1939.

1. Crofting, legislation. This gave security at the cost of perpetuating the 1886 situation.
2. Free trade. Cheap meal lessened the crofter's self-sufficiency and caused him to depend more on auxiliary employment for cash to pay for imports.
3. Education gave Highlanders closer contact with outside world and desire for better living conditions.
4. Failure of sources of additional income—fishing, local industries, etc., is only partly compensated for by road work, tourist trade, etc.
5. Social services have in post-war years given Highlanders a larger cash income.
6. Improvement of roads enabled vans to bring new cheap foods and has revolutionised diet and dress.

Changes more rapid than in almost any other region have been forced on a social economy ill-adapted to meet change. Distance yet loss of isolation and the destruction of the foundations of the old economy, coupled with reluctance to abandon the crofts, have given rise to the present problems.

Excursus.—The bases of the present prosperity of Orkney and the difficulty of producing similar results in other districts.

* * *

Mr. A. D. K. Owen.—The finance of Scottish government.

The union of Scotland with England and Wales involved the co-ordination of two fiscal systems and the disappearance of the Scottish Treasury. The arrangements which were made in 1707 were, on the whole, very favourable to Scotland and they led to remarkably little friction between the two countries.

Broadly speaking, Scotland received more than she gave to the joint Exchequer in the eighteenth century, but this position was reversed in the nineteenth century as Scotland became highly industrialised.

In the present century the development of budgetary policy has favoured a Scotland suffering from industrial depression and rural depopulation. Official figures suggest that she now gets more than she gives, but these figures require some qualification.

An analysis of recent trends in public income and expenditure on Scottish account.

The development of the grant-in-aid for Scottish purposes. An analysis of the present position. The growing strain on the rating system.

The outlook for Scottish government finance.

Mr. A. Cairncross and Mr. G. E. Tewson.—Finance of new enterprise in Scotland.

1. Why new enterprise is needed : long-run trend in the heavy industries unfavourable : lack of second line of defence.

2. Inadequacy of traditional methods of finance of new enterprise.
   (*a*) Growth and proliferation of firms through ploughing back of profits. Ineffective in a period of depression and re-localisation.
   (*b*) The Stock Exchange. The new issue market before and after the War. Relative importance of the Glasgow and London markets as sources of finance for Scottish industry.
   (*c*) Banks, Investment Trusts, Insurance Companies, and other intermediaries.

3. New methods of finance. Government assistance to new enterprise through provision of premises (Trading Estates), revenue (grants from Special Areas Commissioner), and capital (Special Areas Reconstruction Association). The Nuffield Trust and the Scottish Industrial Development Trust.

4. Some suggestions :
   (*a*) Extension of Special Areas. Need to take an industrial unit like the Clyde Valley for a comprehensive planning policy.
   (*b*) Prolongation and extension of the work of S.A.R.A.
   (*c*) Need for permanent Scottish Economic Committee providing information and statistical service.

Rt. Hon. Lord Nigel Douglas-Hamilton.—Some features of the Special Areas in Scotland.

The economic structure of the four Special Areas is very similar and the decline of their industrial activity can broadly be ascribed to the same causes. The social problems which arise therein may have their counterpart in all parts of the country, but still possess distinctive features. Readjustments of industry have been necessary in the past, but the consequences become more serious when carried out without design in a complex community.

The remedy which has been attempted has only been carried a short distance. Its object was to re-invigorate the public services and introduce the newer and expanding types of industry so as to provide opportunities for the inhabitants, at least equal to those elsewhere. Some consideration of the assistance to local authorities, such as baths, sewers, roads, parks, hospitals and clinics is necessary. Pure economic improvement is not easy to achieve. Comparison is made of the economic concessions received through Special Areas' legislation—loans, remission of rates and taxes and the establishment of factories for leasing.

Assessment of results is difficult owing to the great variety of factors, all of which have their influence on any community. The rearmament policy has played a big part, but so also has international uncertainty. The rating system in Scotland presents peculiar difficulties. The entire absence of economic forethought or, in many cases, even power to plan lines of development make the avoidance of chaotic building difficult : the necessity for some form of planning is re-emphasised and anticipation of demand for services.

The artificial limitation of the Areas has presented difficulties, which are the more acute now that the more marked urgency of the problem seems to have passed. Any real solution must be on a long term view, and on such a view the adaptability both of men and the area is important ; adaptability in its turn is dependent on the variety of enterprises which compose that industrial structure. Only when that

variety is established can the Special Areas' problem as such, or the danger of its reappearance be considered removed.

* * *

Discussion on The economics of socialism.

Prof. L. M. Fraser.—What is socialism?

This paper is concerned with distinguishing and sorting out the various issues which go to make up the current controversies as to economic socialism. It is not concerned except accidentally with socialism as a political creed.

Six main strains can be distinguished in socialist economic doctrines. In three different ways socialism constitutes an attack on the principles underlying existing economic institutions :

(*a*) It opposes private property in the means of production ;
(*b*) it demands the substitution of public for private enterprise ; and
(*c*) it calls—or may call—for the substitution of central planning for the existing price system.

In addition, however, stress may be laid by socialists upon

(*d*) the improvement of the economic position of labour, with special reference to the elimination of the threat of unemployment ;
(*e*) the elimination of inequalities of incomes ; and
(*f*) the battle against monopolies and vested interests of all kinds, including such working-class monopolies as trade unions, etc.

These six strains having been distinguished and related to one another it becomes possible to formulate with reasonable clarity the distinction between socialism and (i) communism ; (ii) the trade union movement. Finally the question is asked whether ' national socialism ' is a contradiction in terms.

Prof. A. G. B. Fisher.—Socialism and material progress.

Socialism is primarily a doctrine concerned with means, implying the belief that a planned economy will work more efficiently than one based upon the free decision of individuals. Strictly speaking, the *end* of the plan is irrelevant. But as socialist thought has usually evolved under the stimulus of the failure of existing economies to achieve ends thought desirable by public opinion, socialists often implicitly believe that devotion to such ends—(*a*) higher incomes and (*b*) more stable incomes and employment—is also part of socialist doctrine. The possibility of a clash between them is overlooked, or it is assumed that any policy calculated to achieve the latter will also, as a by-product, achieve the former too. The gravest defect of capitalist economies in practice is their tendency to sacrifice material progress for stability, interpreted as the maintenance of the existing income pyramid, but current socialist doctrine is also liable, in its eagerness to achieve stability directly, to sacrifice material progress. The most pressing practical modern economic problem is the devising of methods to facilitate and accelerate the transfers of productive resources without which material progress is almost impossible, and practical socialist programmes must be tested by their appreciation of this point. It is probable that if measures for raising the level of income are tackled first, the same measures will also be found to be the most effective permanent solvent of unemployment problems, and will at the same time necessitate that reconstruction of the income pyramid which most socialists also approve.

Mr. R. L. Hall.—Some problems in international economics for socialists.

It is not more difficult to construct a theoretical economic system for a Socialist *state* than for other states, since the fundamental problem of scarcity is the same, and the hypothesis that susbstantial equality of income is to be sought introduces

no special difficulty. But the simplicity of treatment exists only for the closed economy under unified control : unless national states which become socialist are willing to merge themselves in a single unit, they must face problems connected with the exchange of goods and the movement of resources. And it is doubtful whether the peoples of wealthy states will agree to complete unification, since the free movement of labour which this implies must lower their standards of living.

Prof. Robbins has suggested that international economic relations between planned economies are likely to be uneconomical, unstable, and productive of friction. These conclusions do not appear to be either necessary or probable for socialist states which do not pursue predatory policies. In these conditions, arrangements resembling those which would be reached with international freedom of trade are quite simple to operate, and offer advantages which should make them acceptable to all national groups. The difficulties connected with the movement of resources are serious, but do not seem insuperable in the case of knowledge and of capital, since there is more resistance to a reduction in the standard of living than to a slowing in a rate of advance. In some cases movements of population may be possible, but these are less likely.

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Mr. A. Beacham.—The Coal Mines Act, 1938, and the future of compulsory amalgamation in the coal industry.

Legislative background provided by Mining Industry Act, 1926 (Part I) ; Coal Mines Act, 1930 (Part II) ; and Coal Mines Act, 1938 (Part II). The latter replaced the Re-organisation Commission (established 1930) by the Coal Commission.

The Re-organisation Commission failed. Chief causes were : (i) Valuation difficulties, especially where amalgamation projected between relatively prosperous and poor concerns. (ii) ' Wrecking Clause ' (1930 Act) laid down very onerous criteria with which schemes had to comply upon penalty of non-ratification. Result was that Commission's advocacy of complete mergers which accentuated these difficulties became less pronounced. Failure to secure ratification of West Yorkshire partial amalgamation scheme brought Commission's activities to an end. The 1938 Act repealed the ' Wrecking Clause ' and reduced power of Court to that of modifying schemes in this respect. The unenforceability of partial amalgamation schemes was upheld. Operation of Act deferred until 1940 with possibility of further delay.

Re-organisation a series of compromises between individual interests and wider interests of industry and society. The latest compromise more satisfactory in certain respects but tending further than its predecessors towards autocratic planning from above. Some doubts also may be expressed concerning the Court's interpretation and application of re-organisation legislation. Finally we may note the influence of coal-owners on legislation and its implications for producer control.

Mr. J. C. Gilbert.—Investment Trusts in Dundee.

The early history of the Fleming Trusts and of the land mortgage companies in Dundee provides an example of the twofold origin of British investment trusts. The history of these two groups of Dundee companies goes back to 1873. The Fleming Trusts were unregistered common-law trusts until 1879, when they were registered as the First, Second and Third Scottish American Trust Companies. No debenture debt was incurred until 1910 and the range of investments was mainly restricted to bonds of railroads in the United States until that year. In 1896 a sister company, the Northern American Trust Company, was formed. This company had wide investment powers and issued debenture stock. The land

mortgage companies issued terminable debentures and invested mainly in mortgage loans in North America. In 1889, as the result of a process of amalgamation, the Alliance Trust, which is now the largest investment trust in Europe, was formed. The Dundee companies pursued a conservative dividend policy and built up large reserve funds. During the post-War period the land mortgage business has been eliminated as far as possible and all the Dundee companies are now general investment trusts. There has been a large expansion in the capital and debenture debt of the companies and a large amount of the short-term debt has been funded.

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Mr. J. H. Wilson.—Exports and imports in the trade cycle.

In a paper read before Section F of the British Association in 1938, Sir William Beveridge drew attention to two newly observed facts concerning British industrial fluctuations : first, the leadership of industries producing for, or dependent on, the export trade into and out of depression ; secondly, the apparent tendency of the British trade cycle, as represented by the general unemployment rate, to turn up or down at a particular time of year, viz. the months July–January.

The present paper represents an examination of the hypothesis put forward on the basis of these two facts, namely, that the decline in the export trades which seems to initiate a depression is a result of fluctuations in agricultural purchasing power. Pre-War and post-War figures have been examined and it has been found that the evident decline in monetary purchasing power is caused by a decline in the *price-level* of imported agricultural goods, their *physical volume* remaining steady. On the other hand the *price-level* of British exports—largely manufactures—remains very steady, actually rising in the first few months of depression. In consequence, the *physical volume* of British exports declines sharply and precipitates a general trade slump.

The second part of the inquiry is devoted to a consideration of the causes of the fluctuations in agricultural prices, and it is suggested that these are the tendency to over-production at times of high price combined with the short-period inelasticity of supply, and powerfully enhanced by speculative dealing. The over-production itself, the evidence would suggest, is due not to physical causes affecting the yield per acre, but to an increase in the acreage planted.

THE ASSESSMENT OF PHYSICAL FITNESS

ADDRESS TO SECTION I.—PHYSIOLOGY

BY PROF. DAVID BURNS, M.A., D.SC.,

PRESIDENT OF THE SECTION.

‘ No mariner ever enters on a more uncharted sea than does the average human being born in the Twentieth Century. Our ancestors thought they knew their way from birth through all eternity. We are puzzled about the day after to-morrow. . . . Never before have we had to rely so completely on ourselves

. . . ordinary men set to deal with problems of heart-breaking complexity. All weaknesses come to the surface.' (Lippmann.)

One of these complex problems involves the whole future of civilised man. The risks and hardships, which in the past ensured that only the fit survived, have been charmed away by the advance of civilisation. No longer are we moulded by our environment. We mould our environment to suit our bodily needs. As a result, instead of the weakest going to the wall, we build a protective wall round them from the cradle to the grave and only permit the more hardy to experience the buffets of a rough-and-ready world. Even they are guarded against many natural risks. The cost of all this protection is enormous. Some ten million pounds per year are paid for doctors and drugs under the Health Insurance Act, and this is small compared with the total expenditure on National Health, Factory Acts, etc. Are we getting value for our money? Is the nation fitter for life since the introduction of the first Public Health Act in 1848?

Are we going the right way to ensure the optimum fitness of the maximum number, or are we merely attempting superficial repair instead of a thorough reconditioning? Is our race degenerating or gradually becoming one of supermen? McDougall (1921) is doubtful. 'Will the human qualities which have carried our civilisation upward to its present point of complexity—will they suffice to carry it further, or even to maintain it at its present level? That is a grave question. But a still graver question calls for our most earnest consideration, namely: does not progressive civilisation—while it makes ever greater demands on the qualities of its bearers—does it not tend to impair, has it not always in the past actually impaired, the qualities of the peoples on whom it makes these increasing demands?'

This is the cry of despondency—of one who allows civilisation to get on top of him instead of using the available scientific powers to control civilisation. Carrel, too, joins the detractors of progress. 'Every living thing depends intimately on its surroundings and adapts itself to any modification of these surroundings by an appropriate change.' He goes on to ask how we have become adapted to modern conditions. Have we benefited? 'It is less fatiguing to work in a factory or office than on the farm. Natural bodily exercises have given way to well-regulated sports—in sheltered arenas. In this way we can develop muscles without being subjected to the fatigue and hardships involved in the exercises pertaining to a more primitive form of life.' He has a somewhat sadistic craving for fatigue, hardships and inclemencies of the weather, and wails that we are growing soft, lack audacity, and don't worry enough.

Can we place any cogent arguments against this distinguished psychologist and eminent biologist and in favour of the ascent of man?

Comparative Death-rates as a Means of Assessing Fitness.

Death-rates interpreted under stringent conditions may be a useful index of the physical fitness of a community. Until the first census in 1801, no accurate general record of mortality was kept. Information was available in London and other large towns in the form of Bills of Mortality published at regular intervals and designed to give information on the number of deaths from plague. Because of the haphazard method of collecting these figures

from the returns of the Company of Parish Clerks, no reliable conclusions can be drawn from them. In 1838 the General Registry Office came into being and, moulded by the statistical genius of Dr. Wm. Farr, as medical adviser, it has regularly supplied accurate figures and periodically issued reports on the state of the population based on statistically valid findings. These reports and supplements are a rich mine of information apparently neglected by the more vocal of our publicists. From such reports and other similar statistical matter (*Year Book* of the League of Nations Economic Intelligence Service) we may learn that the crude death-rate at all ages and in all countries has steadily decreased, e.g. in England and Wales from 21·4 per 1000 (1871–80) to 12·1 (1921–38). In the same period the average infant mortality has fallen from 146 to 59 per 1000 births—a steady saving of infant life which seems likely to continue.

Closer study of these reports shows that certain counties, called by the Registrar-General 'remainder of S.E. England' (Bedford, Berks, Bucks, Essex, Herts, Kent, Middlesex, Oxford, Southampton, Surrey, Sussex and Isle of Wight but exclusive of Greater London), have a lower death-rate at every age under 60 than in the rest of England and Wales. Certain areas, e.g. South Wales, Northumberland and Durham, on the other hand have higher death-rates.

Death-rate in each Age Group.

	0–14.	15–34.	35–54.	Over 55 years.
S.E. England . . .	4·8	2·2	5·7	40·5
Northd. and Durham . .	7·7	3·2	7·5	47·0

Infant Mortality and Rate of Breeding.—That such a difference can occur calls for investigation, especially on the infant mortality rate where the divergence is widest—e.g. Oxford has an infant death-rate of 38, to contrast with 78 in Durham (1934). Even higher infant mortality rates are found in county boroughs. If we are to reduce our general death-rate to 8 per 1000, which Sir B. W. Richardson (1875) claimed should not be exceeded in any district and which is closely approached by New Zealand with 8·5 and Holland with 9·2, we must concentrate on reducing the toll of infant lives as Oxford and these two countries have. We have passed the age when death in infancy was regarded as quite a common thing needing no comment.

'Mamma, I saw a baby dead,
Within a narrow coffin laid.
Its eyes were shut, and cold its cheek :
I call'd it, but it could not speak.
And must I die? my dear Mamma,
I really hope not, I am sure ;
I thought the doctor life could save
And keep us from the dark cold grave.

. . . . . .

So certain as we draw our breath,
So certain we are claimed by death.'

(From *Pretty Little Poems for Pretty Little People, Explanatory of the Operations of Nature, in a Style suited to their Capacities, from the age of Two to Twelve Years*, by Louisa Watts.)

A recent analysis (C. M. Burns, 1939) of the figures for County Durham shows quite clearly that those families who breed at the modal rate and who do not have more than three children have an exceedingly low death-rate irrespective of social class. The modal rate is found among those who have their first child when the mother is between 20 and 25 years old and the next two children spaced not less than two years apart. Since, however, the race cannot be maintained unless the average family contains three children, there must be some families with more than three. It has been shown that, if breeding is carried out at such a rate as to give the best biological conditions, i.e. the fourth child round about a maternal age of 30 and the fifth and sixth child between the maternal ages of 30 and 35, then fourth, fifth, and sixth children may have an expectation of life not significantly worse than in the best families of that size, almost irrespective of economic status.

Breeding at a rate greater than modal or pregnancies outside the modal age limits, i.e. first before age 20 or after 25, increases the maternal and infant death-rates. The rate, lower than in the country as a whole, is higher than it need be in the ' best ' counties and among the more comfortably situated parents because of the tendency of such people to postpone marriage, and thus the possibilities of pregnancy, to an age beyond the modal. In the professional classes, for instance, 36 per cent. of the women who married, did so after they had passed 30. On the other hand, industrial areas have an enhanced figure because many conceptions take place when the mother is too young, and the rate of reproduction is too rapid to permit adequate physiological and/or economic reconditioning.

We are behind three predominantly agricultural countries (New Zealand, Holland and Denmark) in preserving potential citizens. While a man aged 60 is not less unproductive as a worker than a child under 14, the potentialities of the latter are lacking in the former. These three countries (Denmark achieves its inclusion by eliminating the weaklings under one year) have a much lower death-rate during the productive ages, and potentially productive ages, than we have, principally because they have no large industrial towns scattered thickly over their land and hence death and disablement from ' crowd ' diseases is low. Our own farming community compares favourably with New Zealand.

Differential Birth-rates.—Our birth-rate, in common with that of all civilised countries, is declining. The present level of births and infant deaths is largely maintained by those people, about 10 per cent. of the population, least fitted physically, mentally and economically to form the basis for almost 35 per cent. of the next generation. According to Titmuss, ' Our numbers are being increasingly and disproportionately recruited from amongst the unemployed, the unhealthy and malnourished, the mentally sub-normal and from the ranks of those reared in the most unsatisfactory environment and subjected to social and economic hardships.' J. B. S. Haldane says, ' If the existing differences in fertility of the social classes continue we may expect a slow decline of perhaps one or two per cent. per generation in the mean intelligence quotient of the country.' This should give food for thought, as 50 per cent. of our present population have an I.Q. of 85–115, 25 per cent. are below 85, 4 per cent. below 70, and only some 25 per cent. above 115. (Cattell, 1937.)

The men in the only areas where the average reproduction rate is adequate

to maintain the population are not on the whole as fit as in the 'rest of S.E. England.' This is indicated by the excessive rejections of recruits to the Army from these areas, and from figures given by the Ministry of Labour to show the physical health of the unemployed on the Register in October 1934. Over half of the applicants for admission to the Army in 1936 in the Northumbrian region were rejected, or, put in another way, the excess of rejections in this area was 60 per cent. greater than those of the Home Counties. Fisher and Fiske, as the result of an examination of over 10,000 persons seeking 'relief,' state that none were of good physique; some 10 per cent. of the males and 23 per cent. of the women were 'fair,' the others required medical treatment, 10 per cent. somewhat extensive treatment, and 5 per cent. were classed as very bad.

Health and Unemployment.

Men handicapped by a poor physical start in life are still further dragged down by the difficulty of getting and keeping employment. The last to be engaged and the first to go are the unfit. Cause and effect here stretch into the future. Poor health standards and employment handicaps among the marginal families of the community will breed a new generation of C3 citizens unless counteracting factors are put into operation. As a result of the drastic cutting down of staffs during the depression in the U.S.A., men and women who had a history of ill-health formed a large proportion of those without employment—one in every twenty heads of families seeking State relief was unable to work because of chronic disability. (Marsh, Fleming and Blackler, 1938.)

This raises the difficult subject of the extent of morbidity as apart from mortality. The more common causes of premature death are not the most frequent causes of illness. Accurate information on morbidity is hard to get. Figures from insurance companies apply generally to people comfortably off—in general, tax-payers. Sydenstricker and his colleagues made an extensive study of the prevalence of sickness among families (classified by economic status) in Hagerstown, Maryland—a town of 30,000 inhabitants. They found that chronic illness was under 2 per cent. among the comfortable as against over 11 per cent. of the reported illnesses among the poorer heads of families. The study of records of absences due to sickness indicated that, on an average working day, 2 per cent. of the workers were disabled by illness. Male workers lost on the average from 7 to 9 days a year from illness, females from 8 to 12 days.

Health of the Young Worker.—So much for the adult worker of the marginal classes. What of the young worker? In the Annual Report of the Insurance Section of the National Union of Distributive and Allied Workers (February 1939) it is stated that the younger section of their membership was at present exceeding the provision made for them in the valuation basis of the scheme. By the end of 1938, of those who had entered the scheme in 1936 (at 16 years), more than 50 per cent. had tendered certificates of incapacity for work. Over 13 per cent. had been incapable twice, 5 per cent. three times, and 3 per cent. four or more times during the period. Approximately only 5 per cent. of these juveniles had been reported ill during the five years preceding their

entry into membership. The conclusion drawn is that these young people have not the reserves of health necessary for an industrial life. The report concludes : ' It must be remembered that the year selected (1936) covers the 1920 births (the highest post-war birth rate) and that may have some bearing on the problem.'

The Problem.

Not only must birth-rates, death-rates and the toll of those who are clinging to a precarious existence, dogged by ill-health and poverty, be considered in any attempt to assess the fitness of the community, but regard must be given to the age distribution of the population. The death-rate for those whose working days are over has fallen to a very low level and cannot fall much further. This means that, combined with the low birth-rate, the increased longevity of the race will produce a greater proportion of people of high ages. Brownlee (1922) estimates that to get a crude death-rate of 8, some people must live to 125. Be that as it may, we have at present an annual bill for old age pensions of about forty million pounds, and Mr. Duncan Sandys, M.P., told the Conservative Party Conference in September 1937 that in thirty years' time it might easily be sixty-five millions on the present basis of grant. The estimated number of persons in Great Britain of 65 years of age and over would be 4·5 million in 1946 and 5·25 million in 1966. In fact, according to one of themselves, ' We old-age pensioners are now numerous enough to be a political force, and at the next election should refuse to vote for any candidate not in favour of increased pensions ' (W. Couchman). Enid Charles (1938) calculates that while some 12 per cent. of the population of England and Wales in 1935 were over 60 years of age, the figure in 1965 will be about 20 per cent. (*see* Appendix, p. 418).

The children (under 14) and the aged (over 60) will by 1960 form at least 38 per cent. of our nation. With a sex ratio of 0·9, about 30 to 35 per cent. of the population will have to support the remaining 65 to 70 per cent. Direct tax-payers in 1935 numbered about 2½ million and, as it is that class which has the lowest birth-rate and the best expectation of life, we may expect that in 1965 some 1½ million people will have to bear much of the burden of providing not only for their own old age and for the upbringing of their children, but for a steadily increasing number of superannuated and a larger proportion of the children of the poor unless heavier demands are to be made on the indirect tax-payers whose contributions to the State are already a serious burden on rich and poor alike.

' The child of to-day may have to face in his later life and his old age, economic difficulties beside which the lot of the present generation may seem to him, in retrospect, a happy one ' (Lowndes, 1937). Unless the proportion of fit people in the next generation is markedly increased over that of the present population, the economic problem will be insoluble. Hence the discussions of ' experts,' the ' movements ' of uplift groups, the wails of the amateur demographers and the nuncupations of politicians, all of which seem to result, as far as the man in the street is concerned, in a crop of new slogans : ' Drink more milk,' ' Bread for energy,' ' Eat more fruit,' ' Join the keep fit class,' etc., etc. Official posters appear on the hoardings exhorting the populace to do

this or avoid that, all in the name of national fitness. Enormous amounts of money are spent on publicity and, as Carrel says, ' As a result large quantities of alimentary and pharmaceutical products . . . have become a necessity for civilised man.' The aid of Science is invoked, but her advice is generally unheeded in the hasty search for a panacea—an easy way to gain or maintain fitness. The League of Nations (Health Section) appointed a group of experts to formulate the physiological bases of rational physical education and to determine which somatometric measurements and functional tests should be universally recommended as descriptive of physical fitness and form (1938). These international experts state that ' the aim of physical education should be . . . to benefit the whole community . . . and to bring about a sense of well-being.' ' So far, little is available which can furnish objective measures of the physical fitness of the population.' (Stouman and Falk, *Bulletin*, Health Organ., L. of N., 1936.)

What is Physical Fitness ?

The phrase, physical fitness, if I may parody Linklater, is a good phrase. ' We are satisfied with it all unsupported, because it has acquired a numinous quality.' It is one of those magical phrases ' which mean so much to us that, when they are spoken with a proper solemnity, they induce in all who hear them a willing suspension of the critical faculty.' It is a phrase of many meanings. According to some, it denotes fitness for some form of athletics, others define it in terms of industrial output ; others again look only for potential soldiers. Cathcart gives the phrase a wider connotation and speaks of healthy bodies ' well balanced physically, mentally and emotionally, who will be capable of all necessary adjustments to their immediate environment be it work or play.' The fit person will have ' a harmony of motion, a grace of carriage, a pride of body, a mental concentration and quickness of reaction and the happiness and contentment which characterise the really fit ' (1938).

The implications of this summary of the qualities of the fit, involving as it does the bodily frame suitably bound together and moved by muscles controlled by an educated brain and an understanding soul—a definition which includes the whole man, an entity of extreme complexity which acts on and is acted upon by the outer world, animate and inanimate—apparently render the task of assessing fitness well-nigh impossible. One might say with Eliot—

> ' There is no avoiding these things,
> And we know nothing of exorcism,
> And whether in Argos or England
> There are certain inflexible laws
> Unalterable, in the nature of music.
> There is nothing at all to be done about it ;
> There is nothing to do about anything.
> And now it is nearly time for the News,
> We must listen to the Weather Report
> And the international catastrophes.'

Types of Testing.

In other and less exalted words, while accepting Cathcart's definition as ideal let us see how far, using the ordinary routine methods employed by physical trainers and others, we may assess individual physical fitness. Testing may be subjective or objective. In the former, a qualified panel of judges evaluate performance according to some 'sealed specification' in their own minds. This leads to trouble, for it means that they view phenomena through glasses coloured by personal beliefs. There is always a temptation, even in the most rigid thinkers, 'to build up theories and afterwards turn them into articles of faith' (Carrel). When the whole panel holds similar views, its judgment assumes an authority not easily challenged. The judge who dares to disagree with the majority of his fellows is classed as cranky or worse. Further, as Lindhard points out, judgment is apt to be swayed by the principles of conventional art or by current military beliefs on carriage. Objective testing is comparatively easy when one knows what is being measured—that is, a suitable norm or standard is selected with which to compare the unknown. What is an acceptable standard of fitness? A second is always a second, a yard a yard, and a pound a pound, but these units are measured against an arbitrary standard. Attempts to standardise human activities would be disastrous and would remove all interest from life. Even when the type of fitness is specified, human function is so variable, and the same individual may differ so much in his performance from day to day, that it may have no mathematical correlation. Of course, over long periods or in large groups of similar subjects, e.g. sprinters or weight lifters perfectly trained, variability tends to balance out. If the group is sufficiently large, the nature of the test carefully chosen and meticulously carried out, a coefficient of correlation of 0·9 may be obtained. No coefficient under 0·8 in such tests is acceptable.

Training and Fitness.—There can be no doubt of the validity of objective tests when they are applied to measure specific fitnesses. That is, a person may be assessed as fit for a particular performance involving a particular skill under specified conditions; but that is no measure of his general fitness to perform other actions for which he is not trained. 'The first characteristic of the trained man is the greater power to do work for which he is trained' (Zoethout). He works economically, i.e. at a lower calorie cost than the untrained, largely by cutting out unnecessary motions. He carries less fat load in muscle and in the body as a whole, and the concomitant adaptations of the circulatory and respiratory mechanisms are better correlated. He also establishes anti-fatigue habits both of body and of mind. But he has not necessarily an educated body. His apparent excellence may be due to 'cramming' on the part of an instructor, or even to self-cramming. Just as the 'brilliant' scholar of the cram school invariably fails to implement his promise when left to carve his own career at the University, so the 'trained' man is no whit superior to the untrained in carrying out new endeavours. This is clear from the following table (Table I), where the return of the pulse rate after 6 minutes to a figure near the pre-exercise rate is taken as a measure of fitness. Training, then, may be considered as a process of fitting the subject for a particular type of performance. If a country were prepared to entrust all its activities to specialists—one man, one job—and absolutely prohibit

TABLE I.

Subject trained for	Pulse. Before.	Immediately after.	6 mins. after.	Time for race.
	Test = 100-yard sprint.			
100 yards .	84	116	96	12 secs.
„ „ .	82	146	92	12·1 „
„ „ .	88	148	94	11·6 „
Average .	84·7	137	94	11·9 secs.
½ mile . .	78	146	104	12·25 secs.
Football . .	82	126	94	12·2 „
„ . .	84	164	108	12·1 „
Swimming .	88	152	110	11·3 „
Weight lifting .	74	140	102	12·4 „
Average .	81	145	103	12·05 secs.
	Test = ½-mile race.			
½ mile . .	70	176	116	2·2 mins.
„ . .	78	152	84	2·27 „
100 yards .	84	176	100	2·56 „
„ „ .	82	160	96	2·31 „
Out of training	88	148	106	2·48 „
„ „	96	172	116	2·45 „

(Data from Lipovetz, 1938.)

anyone from having a say outside his own job—i.e. a real technocracy—things would be well done and the task of assessing fitness an easy one. In such a state there would, of course, be no room for the intelligentsia, the publicists or the amateur politician. Thought and public spirit would be at a discount, but the machine would work efficiently.

General Physical Training.—What, then, of the so-called general training of the 'keep fit type'? Does this form of exercise keep hand and eye, muscle and brain in trim, ready for anything? Physical training of this type has been common on the Continent for many years and has probably been practised more extensively in Germany, especially in Hitler's time, than in any other country. The 'Hitler-Jugend' is a movement designed to keep young Germany physically fit for its future duties to the state. To quote from the official manual of training, 'Physical efficiency is not only the preliminary condition of your being passed as fit for military service later on, it is also a fundamental demand of the National Socialist view of life. We see in a systematically built up course of physical training an indispensable means of self-instruction in comradeship and in the team spirit. The Führer asks you

to develop your bodily talents and capacities to the utmost ; he wants a Youth Movement in which every individual member unites in himself the God-given Trinity of Body, Mind and Soul. Accordingly, the best German youth is not the wisest or the strongest but rather he whose training befits him to serve his Nation in whatever situation he may find himself.' There is no doubt whatever that the Hitler-Jugend, like our own Boy Scout Movement which it superficially resembles, has caught the imagination of German Youth and it undoubtedly gives a smart appearance to its members, but, either because it is taken too seriously or because of some lack of nutrition, endurance fails. Boys who seem physically alert in October look exhausted in December. The lesson to be drawn is that physical training *per se* had been overdone, and that the responsibility of the future of the Fatherland, and consequently of civilisation itself, lies heavily on bodies, minds and souls too immature to bear the strain. Recent athletic events where German school-boys—the picture of health, beautifully poised and symmetrically developed—were pitted against lean almost ungainly British boys, showed the complete superiority of the latter. Generations of body culture have not apparently reduced the percentage of rejections as unfit for the German Army.

Nature of Tests.

Tests which have been used to assess fitness fall into three classes :

1. Somatometric.
2. Physiological.
3. Psychological.

1. *Somatometric.*

The search for a relationship between the configuration of the body and physical fitness has been pursued since the time of Hippocrates. Such a relationship is elusive, and because of the complexity of body build and the scarcity of strictly comparable measurements, most of the findings lack validity.

It was natural, at first, to consider stature as an index of robustness. The tall man with a long reach was better able to hold his own in hand-to-hand fighting. Even to-day, height is taken into account in selecting recruits for the services and the police. The tall applicant, too, has generally a better chance of getting engaged in commerce and industry than his shorter competitor. Length, especially length of leg, is not merely an indication of genetic constitution but of a late incidence of maturity. Chest girth in relation to size of body, at first sight, appears to have at least a probable relationship to fitness, but Gould (1864), who carried out a thorough statistical survey of the manhood of the American nation during the progress of the Civil War, had grave doubts as to the validity of chest measurements for this purpose. Hutchinson showed clearly that the circumference of the chest is no measure of vital capacity, endurance or even of muscular strength, nor is there any evidence that it bears any relationship to the state of general health.

Criteria of Fitness.—Since the introduction by McLaren of systematic somatometric measurements as part of the routine of physical education there has arisen a host of indices of which perhaps the best known are Von Pirquet's Pelidisi and Franzen's A.C.H. indices. Tait McKenzie (1904)

advocated the use of the thoracic index—the relationship of the diameters of the chest to each other (introduced into anthropometry by Fourmentier (1874) at the instance of Broca). This index, except in the case of abdominal breathers, does give some measure of fitness, in that boys known to be less robust than their fellows have a lower index, 72–73 instead of 74–75 at age 16. It is also well established that suitable physical exercises can improve the index (Mumford, 1927).

Bayer (1939) classifies adult women according to the ratio between two indices. One of these, Si/S, is the ratio of sitting height to height, and the other, Bc/BA, the ratio of bicristal to biacromial width.

In general, chests may be divided into three types: the wine-glass—wide shoulders and narrow hips; the test-tube—both measurements small; and the barrel with broad shoulders and wide hips. Persons of the test-tube type are often abdominal breathers, i.e. they obtain their tidal air by contracting the diaphragm and displacing the viscera into a relaxed abdominal wall. Experiment shows that they have a larger effective vital capacity than the others and are generally more amenable to training. On the other hand, all three types are normal and are equally fitted, as far as bodily relations go, for the battle of life. One cannot mark down any type as fundamentally healthier than the others. The test-tube type is more prone to tuberculosis but less prone to rheumatism, diabetes and arterio-sclerosis than the barrel (Kretschemer, 1925).

None of these indices is valid as a measure of fitness, even when due allowance is made for race, type of body build, sex or occupation.

2. *Physiological Tests.*

Fitness is functional. The body must be tested at work. The measurement of vital capacity is generally classed as physiological although it is not strictly functional. This measurement, a common routine practice, has no real significance. The amount of air that a person can contain in his lungs is a measure of chest capacity and of the tone of the respiratory musculature, but the person with an extra large vital capacity has no advantage over one who has quite a small capacity provided that he has sufficient.

There is a prevalent error that so-called deep-breathing exercises where the shoulders are forced back and the chest brought forwards and upwards increase vital capacity. Actually, by fixing the pectoral muscles and stretching the abdominal wall, these procedures prevent full inspiration and expiration and increase the volume of air left in the lungs (residual air). Chest breathers have about the same V.C., whether taken at ease or on the stretch, while 'deep breathing' may reduce the V.C. of abdominal breathers by about 30 per cent. The value of deep-breathing exercise lies in its effect on the filling of the heart and so on the maintenance of cardiac efficiency.

One is on surer ground when using the various breath-holding tests either *per se* or against pressure. The former is a measure of the alkali reserve of the blood and of the determination of the subject not to give in. The 40-mm. test brings out both these qualities and, in addition, is a severe test of muscular strength and control.

Bainbridge (1931) and Dawson (1935) quote the results of experiments which show clearly that fit and/or skilled men carry out physical work with but

a slight increase in lactic acid, while the unfit, under the same conditions, have a higher blood-lactic acid content. That is, the reserve of alkali in the blood of the fit is large enough to cope with all or most of the acid released as a result of muscular exercise. Recruits have on the average 5 per cent. less available base than the soldiers. The range of alkali reserve of fourteen members of a Physical Education Department was 65–78 vols. per cent., as against 55–71 for twenty-two members of a Medical School (including some ambulant patients). Dawson states that three months' systematic physical education can raise the amount of available base by about 10 per cent. As a matter of interest, about 50 per cent. of trained athletes exhibit mild alkalosis and may give Chvostek's sign of incipient tetany. (Table II.)

TABLE II.

Subject.	*p*H of venous blood.	
	At rest.	During work.
Very fit . . .	7·42	7·40
Fit . . .	7·44	7·38
Less fit . . .	7·45	7·36
Not fit . . .	7·42	7·27

(Bock *et al.*)

Similar 'fitnesses' associated with other groups of muscles can be tested by various dynamometers. Martin (1918) introduced a new procedure into this type of test. Instead of measuring the strength of a subject's active pull on a dynamometer, he applied the pulling force to groups of muscles and recorded the force necessary to break down the subject's active resistance to the movement of the muscle-group under test. The summation of a series of selected groups of muscles thus gives an indication of the total muscular strength of that individual as well as of his determination to resist. It gives no measure of his skill or of his economy of movement. It may be asked, is muscular strength plus determination an adequate measure of general fitness?

Limiting Factor of Efficiency.—It is well known that the limiting factor, the factor which determines whether muscular strength can be exerted to its full extent, the factor which overrides the will to do, is vaso-cardiac efficiency. Goodall (1916) recognised this when he published his efficiency tests. If, after a measured amount of exercise, the pulse rate and blood pressure come back to normal in a specified time, depending on the severity of the exertion, then the subject of the test is fit. This stressing of the time for restoration to resting level is one of the fundamental facts taught by Sir James Mackenzie. The time occupied by the discharge of energy is almost constant, the time occupied by renewal is variable, depending on the efficiency or otherwise of the functioning of living cells.

With a healthy heart, cardiac efficiency ultimately depends on the venous

filling. A pump without a well may be a thing of beauty, the last word in mechanical efficiency, but its usefulness is non-existent. About 85 per cent. of the total volume of the blood is in the capillaries and veins under normal conditions. Under these conditions, all capillaries are not patent at any one time. The splanchnic viscera, and particularly the liver and the spleen with their rich venous supply, are capable of retaining much larger quantities of blood than they do. If, for any reason, more capillaries open up at the same time and the splanchnic reservoir becomes filled with blood, the amount freely circulating, the amount necessary to fill the receiving chambers of the heart becomes inadequate. (Table III.)

TABLE III.—*Approximate Distribution of Blood in Man at Rest.*

	In ml.		
Systemic circulation .	2,310		Plesch.
Pulmonary circulation .	2,190		Plesch.
Total volume . .		4,500	
Residual blood in heart .	150		Dawson.
Arteries . . .	450		Plesch.
Veins and sinuses . .	1,400		Plesch.
Capillaries . . .	2,500		
Total volume . .		4,500	
Skeletal muscle . .	1,350		Spehl.
Lungs	1,000		Stewart.
Liver	1,000(?)		Barcroft.
Skin	500		Barcroft.
Spleen	300		Hartwig.

Muscle Tone.—The controlling factor in the distribution of blood, in maintaining an effective circulation, lies mainly in the tone of muscle—cardiac, visceral and, last but by no means least, ordinary skeletal muscle. If a trochar attached to a manometer is placed in the right atrium of a deeply narcotised animal whose pulmonary artery is clamped, a pressure of 100–120 mm. of water is recorded, and if the blood is allowed to escape, a half or more of all the blood in the body gushes out (Riml, 1929). 'Where does this blood come from and what is the force that drives it through the veins towards the heart? Obviously it comes from the reservoirs of blood in the tissues. Obviously also the heart is not involved; for its force is abolished by the clamp on the pulmonary artery. The pressure is produced within the tissues, and is due to their tonus; for it disappears along with their tonus a few minutes after death. Muscle tonus is therefore the force that produces this pressure and with it the flow of the blood through the veins to the heart' (Henderson, 1938).

The venous return is also aided by the rhythmic alterations of intra-thoracic pressure with the phases of the respiratory act. It is, however, only in abdominal breathing that the respiratory act aids the return of blood to the heart (Lewis, 1908). These alternating pushes and pulls, produced by muscular action dependent on the tone of the diaphragm and muscles of the abdominal wall, have a minor effect on venous return in comparison with the constant

tonic push of muscle in general. During exercise, more capillaries in muscle become patent and, if muscle is in good tone, more blood is put under tissue pressure. On the other hand, if tone is at a low level, blood filling the capillaries is not pressed out, congestion appears and the heart fails through lack of blood. The fit person whose heart is able so to increase its output per unit of time that adequate blood is supplied to active tissues to meet their increased needs, must have a higher value of muscle tone than the unfit. Experiment shows that healthy young men have a tone in their relaxed left biceps muscle which is capable of withstanding a pressure of 60–90 mm. of water, while patients in bed have an intra-muscular pressure of about 50 mm. H_2O.

Intra-muscular pressure is markedly increased when muscle contracts, so that, as the fibres in muscle shorten intermittently during exercise, the blood is expelled from the venules in the muscles intermittently. This pulsation plays an important part in maintaining the tone of the vessel walls. The hæmostasis produced by immobile standing, shown by swelling of the legs in unfit persons, may be prevented by almost imperceptible voluntary twitches of the calf muscles or even by movements of the toes. Standing rigidly at attention is a severe test of the efficiency of the mechanisms responsible for the venous return to the heart.

Muscular tone is dependent on many factors—adequate blood supply, absence of excess of fatty upholstery, a regular arrival of motor impulses to the muscle controlled from higher centres and a cooling mechanism nicely co-ordinated to the needs of the moment. It is easy to demonstrate that faulty heat loss lowers tone. The avenue by which heat is lost is apparently unimportant, but, unless under the artificial conditions of the laboratory where even loss by radiation can be made the effective sole method of losing heat, the evaporation of moisture from the skin is the usual limiting factor (Mills and Ogle, 1939). Several investigators have shown that the phenomenon known as 'second-wind,' by which a runner experiences a sudden relief from the agony of breathlessness and the leaden drag of weary muscles, is accompanied by sweating. When this occurs, alveolar CO_2 falls, the urgency of breathlessness fades, the head clears and the muscles act with renewed vigour.

Measures of Fitness.—Three means of measuring fitness are thus indicated, and they are interrelated :

(*a*) Tests of recuperative efficiency. The ability of the cardio-respiratory mechanism to return to normal functioning within a limited time after exertion.
(*b*) The ease of heat loss under specified conditions.
(*c*) The value of muscle tone.

(*a*) Tests such as Goodall's, Crampton's, Foster's, McCurdy's and Schneider's, which depend on arbitrary scoring for rise of pulse rate, blood-pressure and respiration rate after exercise, and scoring for the length of time for a return to pre-exercise levels, have a very low coefficient of reliability. Schneider's is the best with an $r = 0{\cdot}4$. McCloy prefers to measure alterations in diastolic pressure and pulse rate on standing erect after lying supine. This had an r between $0{\cdot}8$ and $0{\cdot}9$ in a limited study of healthy and convalescent golfers.

Turner's test, which depends on the cardio-vascular reactions during

standing absolutely still for 15 minutes, has a coefficient of reliability of over 0·9 for adults but yields anomalous results with boys. In Schneider and Crampton's studies of pre-adolescent boys (1935) the boy proved least fit by all other tests was the sole survivor at the end of 15 minutes' standing (with a pulse pressure of 8 mm. Hg !). The others had either given in or had fainted.

The rate at which the oxygen debt is repaid may be used as an index of physical solvency. The fit subject either pays cash to close the transaction or demands short credit. The percentage of the total debt liquidated during 3 minutes after the cessation of exercise is, in the case of the unfit, about 30, while the same subject, in condition, may have discharged over 60 per cent. of his debt. The drawback to the employment of tests of recuperative power is the possibility of overstraining the vaso-cardiac mechanism in the unsound.

(*b*) No large series of experiments has yet been planned to gauge the reliability of this test of efficiency.

(*c*) The value of muscle tone may be determined in various ways. Coffey, Barnum and Henderson (1910) used the knee-jerk as an index of tonus. Even when absolutely uniform strokes of the hammer are applied to the patellar tendon of a co-operating subject, variable degrees of the extent of kick are obtained with successive stimuli. It is a useful method to demonstrate the gross alterations for which these workers used it, but, principally because it requires a trained subject for accurate results, it is not of general utility. The direct reading of intra-muscular pressure (Hellebrandt, 1939) is awkward and somewhat unpleasant for the subject. Several attempts have been made to link creatinine excretion with muscle tone (Schaffer, 1908). 'Other things being equal,' say Daniels and Hejinian (1929), 'the infant who has a high creatinine-length coefficient is the more nearly physically fit.' Daniels, Hutton and Neil (1938) showed that in children up to 6 years of age, those physically fit (private subjects) had higher coefficients (mg. creatinine $\times$ $1000/ht^3$ in cm.) than the less fit (and less well off) subjects. All with a coefficient below 0·264 they class as 'ill-nourished.' Unfortunately, in these experiments (and many others on older subjects) little or no regard was given to the amount of meat eaten. 'There is no parallelism between the amount of flesh eaten and the increase in the excretion of creatinine. Estimations of the excretion of creatinine, while the subject is on a flesh-containing diet, are quite devoid of value, even though the amount of flesh in the diet is kept constant' (Burns and Orr, 1916). For the same reason, lack of strict control of dietary constituents, the exhaustive work of Jellinek and Looney (1939), on some biochemical constants of thirty men who had been carefully selected and rigorously examined to ensure physical fitness, must be accepted with caution so far as their creatinine findings are concerned.

Noël Paton, in his Presidential Address to this Section at Bournemouth in 1919, put forward the suggestion that the maintenance of muscle tone (and hence of physical fitness) depended in part on the presence in tissue-fluid of small quantities of guanidine or its methyl-derivative. He showed unequivocally that muscle, either of warm- or cold-blooded animals, increased in tone when minute amounts of the salts of this base were administered. Since then much work has been done to elucidate this problem. Sullivan (1935) was able to estimate the urinary guanidines in cases of progressive muscular dystrophy before and during treatment. As the cases improved, under

glycortal medication, simple guanidines disappeared from the urine. More recently, Minot (1938) has successfully treated patients suffering from this disease by oral administration of guanidine hydrochloride; and Dewar, working in my laboratory, has confirmed this (using the tasteless carbonate). Unfortunately, exhaustive search has failed to find a reliable method for the estimation of urinary or blood guanidine, and so, as a test of tone, the determination of the simple guanidines is, at present, unavailable.

Noël Paton thought that the point of action of this alleged hormone was on the motor nerve-endings. Work in my laboratory has shown clearly that the sensitivity of the sympathetic nervous system is markedly enhanced by extremely small amounts of guanidine, and so we assume that the tone of muscle must in part at least depend on the integrity of this nervous system. This view is not invalidated by the alterations in tone reported by Henderson (1938) in a sympathectomised cat. If our view is right, adrenergic fibres must pass to muscle with the motor outflow—an outflow not interrupted by sympathectomy as generally performed.

The sympathetic control of muscle tone has been the subject of many investigations and much controversy. There is a wealth of indisputable evidence that the anatomical sympathetic system plays, at best, a minor part in the direct maintenance of muscle tone and no one now holds the views of Hunter or of Royle. On the other hand, the work of the Orbeli school, amply confirmed by later experimenters from other laboratories, points to the influence of adrenergic nerves on the neuromuscular mechanism. This influence is shown more clearly when the action of the vasoconstrictor fibres is removed by poisoning with ergotoxine. This may be taken to mean that the main function of the sympathetic in the maintenance of muscular tone lies in ensuring effective vasodilatation of the muscle capillaries (Rosenblueth and Cannon, 1935) brought about through the so-called ‘nutrition reflex’ (Hess, 1930; Fleisch, 1935). The fit man, with good muscle tone, soon stops the drain on the blood supply to skin and viscera, while the unfit keeps the pallor of skin for some time and may even show signs of acute digestive upset. One may, therefore, test fitness by estimating the degree (amount × time) of the deprivation of the skin of moving blood.

The responsiveness of the sympathetic arm of the reflex arc depends on the functioning of the cortices of the suprarenal glands (Secker, 1939). This pair of ductless glands with a long ancestral history is absolutely necessary for life and is affected by any undue strain on the reserves of strength. The will to endure, to keep going on, is mental, but the power to force an unwilling body to obey the order of the mind, to exert its last ounce and not die in the last ditch, depends, in the end, on the adequacy of the secretory mechanism of the cortices suprarenales. Animals with grafts of cortical tissues and no medullæ act as normals (Ingle, Hales and Haslerud, 1936). Injection of cortical extract to completely adrenalectomised rats restores voluntary activity to an extent depending on the amount of cortin given (Ingle, 1936). Hypertrophy of cortical tissues follows exercise in the rat (Anderson, 1935). ‘Possibly,’ says Dill (1936), ‘one of the effects of training is to increase the secretory activity of the adrenal cortex.’

The sequelæ of severe muscular exercise under conditions where cooling is inadequate differ only in degree from those of cortical insufficiency, i.e. loss of

muscle tone, increase of blood potassium and lowering of blood sodium both absolutely and relatively. The loss of tone may be due to imbalance between the metallic ions as well as to exhaustion of cortical supplies as it may be mirrored in normal subjects by administration of salts of potassium.

3. *Psychological Tests.*

The fit man carries on his work and his play without an unpleasant degree of fatigue, and so his industrial output may be taken as a measure of his fitness. The amount of work done or the goodness of the work done depends not only on the physical state of the worker but on the state of his mind. It is well known that work which is in itself pleasant or leads to pleasure as a more or less remote result is carried out with an efficiency lacking in more formal performances or in forced work. L. Hill (1898), Gillespie (1924) and many others have shown that the initial cardiac acceleration followed by peripheral and splanchnic vasoconstriction leading to an increased venous return to the heart with consequent cardiac retardation and increased output is mainly psychical in origin. If the work is uninteresting or the movements passive (Martin *et al.*, 1914) these preparatory circulatory changes do not take place and the organism as a whole is thus less fitted to do work. Investigations involving treadmills, stationary running, bicycle ergometers, etc., may thus fail to reveal accurately the efficiency of a subject because of the more or less complete lack of interest of the work once the novelty has worn off. The performance becomes a routine and the efficiency consistent but low. On the cessation of the mental effort, the tone of muscle falls, the peripheral and visceral vasoconstriction passes off and output falls. One of the conclusions, drawn from the results of many exhaustive investigations made in the U.S.A. and in this country, is that good sociological conditions are of paramount importance if good work is to be expected. Even apparently trivial improvements in amenities lead to increased output. For example, the average output of relays per hour in the Western Electric factory at Chicago of 55·7 when lunch was provided by the management, rose to 66·4 when the employees supplied their own lunch. This rate was maintained over two periods of 31 weeks (of the observation period) and was a record (Whitehead quoted by Dill). Hitler realised this principle, in theory at least, when he instituted his 'Strength through Joy' movement.

Value of 'Stunt' Tests.—Cathcart places great value on the ability to react rapidly and accurately to changes in the environment. Efficiency in this can be tested by presenting the subject with exercises which demand new co-ordinations as well as motor activity with a performance both easy and graceful. This type of test, as outlined by Brace, McCloy and others, has a coefficient of validity of over 0·8.

Exercise and Fitness.

What, then, can be said of the effect of exercise in maintaining fitness? The Committee of the Health Section of the League of Nations is rather despondent on this matter. They say, 'Up to the present, methods and systems of physical education have not produced any clearly demonstrable

effect on the health of the masses, doubtless because the present state of our knowledge is not as yet sufficient to enable us to base them on accurate scientific data ' (1938).

Properly designed exercises, carefully controlled, can be used to correct faults of carriage, to eliminate uneconomic muscular actions and fit the mildly dysplastic to take their place without shame among the euplastic. The danger of such exercise lies in any attempt to create an ' ideal ' posture, etc., which has no physiological foundation.

Exercise carried on without strain or undue fatigue keeps the body in tone; and some exercise is considered beneficial to those engaged in sedentary occupations especially, as it increases the venous return to the heart and prevents stagnation in the blood reservoirs and lower limbs. The group of experts of the Commission on Physical Training were therefore enjoined ' to determine the minimum amount of physical training required to ensure the normal health of the individual.'

Exercise designed to ' build muscles ' beyond the needs of that particular person merely leads to increased food intake, and when, because of age or lack of opportunity, the amount of exercise is decreased, fibrous and fatty degeneration and infiltration takes place. While it may be ' better to have lov'd and lost,' it is certainly not better to have exercised and stopped.

Probably the main beneficial result of keep-fit classes and similar movements is the inculcation of a spirit of independence, personal confidence and pleasure in performance. Although ' the healthy body works in silence ' (Carrel), the fit person has a keen sense of the enjoyment to be obtained from suitable exercise. The physiological foundation of the exhilaration resulting from exercise—an exhilaration not entirely due to a decreasing handicap at golf or competitive improvement at other games—would be a suitable and profitable study for ambitious politicians and others.

While it is true that one cannot assess a man's efficiency till his whole life's story has been unrolled (and then it is too late to do anything about it), one should be able to establish norms related to age and sex. The recent Military Service Act provides an occasion for the audit of the nation's young manhood, and, provided suitable tests are applied by properly trained examiners, a beginning will have been made to the collection of facts and figures from which much may be learned.

There is no doubt as to the improvement in mental and physical fitness that results from wise physical training, co-operative effort and good feeding such as that obtained in military camps of the best type. Such training may go far towards reconditioning some of the youth of the country. The American Department of Labour, in a report (1935) on two years' experience of civilian conservation camps, says, ' Thousands of actual case records reflect the fact that the C.C.C. men have returned to their homes definitely benefitted physically and mentally; their outlook toward the future is brighter, their sense of self-reliance and their ability to adjust themselves to economic conditions is stronger.' To this tribute to wise and varied physical, mental and moral education one may add the results of a short experiment in effectively reconditioning a selected number of rejected recruits for our own Army. ' My predecessor started a depôt for training a limited number of men who were below standard and, as a result, . . . 576 of the 600 . . . have

reached the full standard of fitness' (Right Hon. L. Hore-Belisha, Devonport, 1937).

While not in any way detracting from the importance of work of this type on men during late adolescence and early maturity, one may ask why the audit is not made earlier in the course of our national business of turning out citizens—taken early before the debit balance of wasted lives becomes so large that strenuous measures have to be taken to safeguard our interests. No factory whose products were good, bad and indifferent would exist long before the shareholders were demanding an inquiry and a change of directorship.

Our national strength lies in our men and women and not in the machines that they tend or the battleships that they man. To be really great a State must have citizens fit in body and also in mind. 'The health of the intelligence and of the affective sense, moral discipline and spiritual development are just as necessary as the health of the body and the prevention of infectious diseases' (Carrel).

To ensure this would cost money, but so does radium. The chief use of this rare element is to prolong the life of the aged ; should we not be equally ready to foot a bill which would make young lives more fit to bear hopefully and without undue strain the heavy burden their ancestry has laid on them? —so that with Walt Whitman we may see

'Journeyers gaily with their own youth,
Journeyers with their bearded and well-grained manhood,

. . . .

Journeyers with their own sublime old age:
Old age, calm, expanded, broad with the haughty breadth of the universe.'

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APPENDIX (*see* p. 404).

From the report of a debate in the House of Commons (July 20, 1939).

'Mr. Chamberlain said: "I am presenting a very serious argument. What is going to be the result of this increased expectation of life, coupled with the diminution in the birth-rate, which is going on at the same time? In 1931, the number of persons of 65 years and over was, in proportion to the number of people between 15 and 65—the earning age—as 11 to 100. In 1955, that will have risen to 16 to 100, and, in 1975, to 20 to 100. It may be said that that is a long way off and we shall not know anything about it, but surely we ought, if we have a proper sense of responsibility, to consider what is going to be the effect on the next generation of anything that we may be doing to-day. I would put this point to the House. The implication of the figures I have given is this: That as time goes on there will be an increasing proportion of the population who will be eligible for pensions and to whom pensions will have to be paid, and there will be a decreasing proportion of the population who will be earning wages and therefore able to make contributions to pay them."

'In 1930, after the Contributory Pensions Act was passed, the cost to the Exchequer was £46,000,000. The estimates for the current year showed a charge of £69,000,000, and in the course of the next forty years the estimated annual cost will rise to £115,000,000 at the present rates of payment.'

SECTION I.—PHYSIOLOGY

COMMUNICATIONS

Discussion on The problem of pain. (Held in the Department of Physiology, Bute Medical Building, St. Andrews.)

Prof. D. Waterston.—The problem of pain.

The advances in our knowledge of pain in the past fifty years, and especially the work of Sir James Mackenzie. His concept of 'referred pain' or the viscero-sensory reflex, and the mechanism of its production.

The response of somatic tissues and of the viscera to pain stimuli.

The theory of the production of pain by 'over-stimulation' of afferent (sensory) nerves and that of the existence of pain nerves.

The work of Sir Thomas Lewis and the theory of a 'nocifenser system' of nerves, and the production of a 'pain-producing substance.'

The relation of the cerebro-spinal and of the autonomic nerves and of the cortex and thalamus.

Recent views on the peripheral and the central causation of pain.

Prof. John Morley.—The dual mechanism of pain in disease of the gastro-intestinal tract.

Mackenzie's observations on insensitivity of the gastro-intestinal tract, and his rejection of Ross's theory on splanchnic pain. His elaboration of Ross's theory of radiation of pain from viscera to parietes through an 'irritable focus in the cord.'

Mackenzie's inability to distinguish between referred pain from parietal peritoneum and from intra-peritoneal viscera.

Critical examination of Mackenzie's theory of abdominal pain.

Ross's view of splanchnic pain is supported by experiments on man.

Lack of clinical evidence of reflex rigidity and tenderness in pure intestinal obstruction, e.g. in strangulated hernia or gallstone obstruction. Clinical findings in early acute appendicitis incompatible with Mackenzie's theory.

Importance of radiation of pain to shoulder-tip on stimulation of phrenic nerve endings, because 3rd, 4th, and 5th cervical segments have no visceral connections. Peritoneo-cutaneous radiation of pain and peritoneo-muscular reflex explain deep tenderness and rigidity in abdominal wall. Recent work of Kellgren and Lewis.

Importance of nerve-blocking experiments, and doubts concerning the 'irritable focus' theory.

Pain from urinary system harmonises with Mackenzie's views though gastro-intestinal pain does not.

Prof. B. A. McSwiney and Dr. B. M. Unkauf.—Visceral afferent fibres.

Dilatation of the pupil in the cat anæsthetised with chloralose and reflex changes of blood pressure in the spinal and decerebrate cat and in the cat anæsthetised with chloralose have been used as indices of visceral afferent impulses. It must be pointed out, however, that these methods do not indicate the character of the sensation.

The gastric and duodenal mesenteries are supplied by the vagus and splanchnic nerves, while the jejunal mesentery appears to be supplied by the splanchnic nerves. The mesenteries are sensitive to traction.

The body of the stomach, pyloric antrum and pyloric sphincter are sensitive to distension and are supplied by afferent fibres in the vagus and sympathetic nerves.

The stomach and duodenum are supplied by afferent fibres from the right and left vagus nerves and the right and left splanchnic nerves. The jejunum and ileum are much less sensitive to distension than the stomach and duodenum. The right and left splanchnic nerves appear to be the main afferent pathway from these regions.

The ileo-colic sphincter and the large intestine are also sensitive to distension. The sphincter is supplied by afferent fibres from the right and left splanchnic nerves and from fibres which enter the spinal cord by the dorsal roots of the lower thoracic and the upper lumbar segments. The large intestine is supplied by afferent fibres which join the lumbar sympathetic chains and enter the spinal cord by the dorsal roots.

The highest and lowest levels of entry into the spinal cord of the afferent neurones of the pupillo-dilator reflex are shown—

Area stimulated.	*Upper limit.*	*Lower limit.*
Fundus and body of stomach	T3–T4	T13
Pyloric antrum	T5	T13
Pyloric sphincter	T5	L1–L2
Duodenum	T6	L1
Jejunum	T7	T12–T13
Ileo-colic sphincter	T7	L2
Large intestine	T7	L2

Visceral afferent fibres from either splanchnic nerve, and somatic afferent fibres from the intercostal nerves ascend contralaterally and ipsilaterally in the lateral columns of white matter. Those pupillo-dilator fibres in the splanchnic nerves and in the intercostal nerves which ascend contralaterally, cross the spinal cord in the segment above that by which they enter the cord.

The function of the visceral afferent fibres is discussed.

Prof. J. Chassar Moir.—Observations on uterine pain.

There is evidence that the uterus behaves like other visceral organs with regard to sensibility. It can be cut, crushed, or seared with cautery without causing pain to the conscious woman. Vigorous scratching or tearing of the mucosa will, however, cause some discomfort, and in this the uterus seems to differ from other hollow organs. Distention of the pregnant or non-pregnant uterus, and especially stretching of the tissue in the neighbourhood of the internal os, provokes intense pain. While there is no clear evidence to show whether uterine pain is or is not a true visceral sensation, it is fairly certain that the pain is, in part, a referred sensation. For example, certain forms of stimulation to the cervix will at once cause severe pain which the patient describes as being felt over the sacrum. There is strong evidence that the pain of labour is not due to muscular contraction *per se*, but is largely caused by distention and deformity of muscle of the lower uterine segment and cervix. In certain rare circumstances intense uterine spasm may also cause pain. This has been seen in a few instances after delivery as the result of an injection of pituitary extract. The severe pain of spasmodic dysmenorrhœa is also probably caused by uterine muscle contracting, and continuing to contract, in the absence of a free blood supply. The intra-uterine pressure in such cases may exceed the patient's blood pressure. Such pressures are far in excess of those reached during labour.

Mr. T. F. Todd.—Intra-thecal alcoholisation.

Intractable pain is relatively rare and is most frequently found in association with advanced malignant disease. Previously morphia was the only remedy, but

to-day surgical methods offer an alternative treatment which avoids the depressing sequelæ of morphinism.

Assessment of pain.—Objective criteria of pain assessment are lacking. Can the physiologist devise some instrument like the Summers 'Pathometer' to enable us to estimate the degree of pain?

Personal Experiences with Intra-thecal Alcohol.—Approximately fifty cases have been given intra-thecal injections of alcohol; all were suffering from pain in the pelvis or lower limbs associated with advanced malignancy, mostly carcinoma of the cervix. The results have been very gratifying. In over three-quarters of the cases more or less permanent relief of pain has been obtained. In half the remainder there has been an appreciable degree of relief and in four or five cases only has there been a failure to give relief. The failures have been associated with bone metastasis, spinal cord compression, or established morphinism. The technique is not complicated and if care is taken complications can be mostly avoided. The average duration of relief is three to four months.

Discussion on physical fitness.

Col. R. B. Campbell, C.B.E.—The psychological aspect of physical education.

I. Physical education the science of movement—movement and life—the scope of physical education in the conduct of life.

II. The upward trend of movement in the evolution of mankind—the significance of the upright position—the advent of the thumb and its influence in the development of the mind—the training of the senses and their force in physical education.

III. The influence of thought on the functions of the body—the power of the emotions in physical action—the unity of mind—body—spirit.

IV. The ethics of play—games and temperament—selection of games—the principles of training.

V. The spirit of self-effort—character and training—progressive stages in individual development—physical education to fit in with the rhythm of life.

VI. Mind and movement—thought and action—physical expression and its psychic equivalent—psychological interpretation of voluntary movement—the moral aspect of physical education.

VII. The measurement of movement—physical ability tests—their value and purpose in the direction of physical education—their stimulus to self-effort. Self-effort and leadership—leadership and team-work—team-work in education.

Miss Helen Drummond.—The contribution of physical education towards physical fitness.

Is physical education really necessary in childhood and adolescence?

The dependence of success upon the attitude of the child himself, the home and the school.

Physical education in adult life. The fitness movement.

The training and approach to work of the teacher or leader.

Prof. A Hemingway and Mr. H. R. Noltie.—Respiratory exchange measured during distance running.

Oxygen consumption and carbon dioxide output were measured, using expired air samples collected by the Douglas Bag method, during steady running for eight to sixteen laps on a quarter-mile cinder track.

Despite a steady rate of running the respiratory exchange was by no means

steady. The oxygen retention tended to fall off after about eight laps though the carbon dioxide output remained fairly steady.

After seven weeks' absence from track running, though not from other forms of exercise, oxygen consumption was found to rise more slowly than before, whilst the carbon dioxide production was no higher and at a maximum about the sixth lap.

* * *

Dr. F. W. Edridge-Green, C.B.E.—The double function of the ocular muscles.

The most important part in photography is the film, and a fresh film is required for each photograph. This is accomplished in the eye by the pressure caused by the contraction of the eye muscles. If a light be attached to a scale in a dark room and a point three feet to the right be marked with a peg, and the light be looked at with one or both eyes for one or two seconds from a distance of ten feet, and then the eyes be directed at the peg, it will be noticed that the negative after-image of the light is seen on the peg, but the positive after-image has rapidly passed it to the right. The eyes being directed towards the peg, it will be noticed that the positive after-image comes rapidly back towards the peg. The first part of the experiment has been described before, and it is evidently due to the contraction of the eye muscles pressing on the eye and moving the photo-chemical fluid, thus causing a separation of the positive and negative after-images. The second part of the experiment appears to be due to the cessation of the pressure on the eye causing the photo-chemical fluid to flow in the opposite direction. It should be noted that the pressure is in the opposite direction to the movement of the image ; thus, when the pressure is to the left the image moves to the right, corresponding to the new position of the fluid in the retina.

This and numerous other experiments can only be explained by the author's theory of vision which assumes that the cones are the sole percipient elements and that the rods are the nerve elements which sensitise and regulate the photo-chemical film.

MEASUREMENT IN PSYCHOLOGY

ADDRESS TO SECTION J—PSYCHOLOGY

By R. J. BARTLETT

PRESIDENT OF THE SECTION

In the opening paragraph of *Psychology down the Ages* Prof. Spearman concludes a list of difficulties, facing any who seek to define psychology, with the questions : ' Do the data at its disposal include what can properly be called " measurements " ? Is it, or can it ever hope to be, or should it as much as try to be, a systematic science at all ? ' Dr. William Brown, in the realm of Medical Psychology, answers the first question in the negative. Forced into metaphysics, he writes : ' Determinism, although a postulate for psychology, cannot be accepted as anything proved. In physical science there is empirical proof of it to a certain extent through measurement. By measurement we can prove to a certain extent, within certain limits of error, the conservation of

mass, the conservation of energy . . . But there is no measurement of that sort possible in psychology . . . The observations of psychology are primarily qualitative, not quantitative.' [1] But the writer of *Essentials of Mental Measurement* could not leave it there. He added a footnote : ' But mental measurement, in a derived form, is possible in the domain of mental tests and of the psycho-physical methods.'

The conflict between philosophy and experimental psychology, thus exemplified, is of long standing. Malebranche argued that mental states could be distinguished qualitatively, but not quantitatively. Leibniz declared that mathematical treatment was impossible in psychology as it lacked continuous magnitudes. Kant said that psychology possessed no mathematical magnitudes for the reason that, ' whereas the phenomena of matter possess two variables, space and time, those of mind have only the single one, time.' [2] For these and many later philosophers psychology possesses neither measurable phenomenon nor the means to measure. Still worse ! Some physicists seem to have reached the same conclusion. For them measurement is impossible in psychology.

In 1932 a committee of Sections A and J was appointed to consider and report upon the possibility of quantitative estimates of sensory events. Last year this committee ended its interim report [3] with a request ' for reappointment to consider whether the views put forward (therein) are, or are not, irreconcilable.' They now report that agreement seems impossible. If all measurement must conform to the Laws of Measurement enunciated by Dr. Campbell,[4] and, in particular, if the second law can only be satisfied by the physical juxtaposition of equal entities, then sensation-intensity cannot be measured. Yet this standard would have imposed a severe handicap in the early days of natural philosophy, and, maybe, some sciences must still be allowed greater latitude. The alternative would seem to be the coining of a new title for much that is called measurement.

Notwithstanding criticism from philosophy and physics the word measurement is deeply imbedded in the literature of psychology, and of late years its use has been greatly on the increase. Experimental psychology is little more than fifty years old. Galton's *Inquiries into Human Faculty* appeared in 1883, Wundt went to Leipzig in 1875, Weber died in 1878 and Fechner in 1887. Since then an ever-growing body of workers has been applying experimental method to psychological problems and developing its own methods of measurement and mathematical treatment of data obtained. Contemplating this work against the declaration that measurement is impossible in psychology Prof. Spearman comments : ' But the path of science is paved with achievements of the allegedly unachievable. And in point of fact, mathematical treatment is perhaps just the region where psychology has made its steadiest and most surprising advances.' [5] My task is to attempt a review of experimental psychology that will reveal the senses in which the word measurement is being used by psychologists.

[1] *Psychological Methods of Healing*, p. 51 (1938).
[2] Spearman, *Psychology down the Ages*, p. 89 (1937).
[3] Report, 1938, pp. 277–334.
[4] Campbell, N. R., *Measurement and Calculation* (1928).
[5] *Psychology down the Ages*, p. 89 (1937).

First, however, a few words on the meaning of *measurement* as given in the *Oxford English Dictionary* may not be out of place. Perhaps the nearest approach to the physicist's meaning, there given, is: 'To ascertain the spatial magnitude or quantity of (something); *properly*, by comparison with some fixed unit.' At the other extreme we find Hobbes' 'Men measure, not only other men, but all other things by themselves,' and Jeremy Taylor's 'Measure your desires by your fortune.' Between these meanings we find: 'That by which anything is computed or estimated'; 'To appraise by a certain standard or rule or by comparison with something else,' and, of still greater interest in view of the immaterial nature of things mental: 'To estimate the amount, duration, value, etc., of (an immaterial thing) by comparison with some standard.' It would seem that 'appraise' and 'estimate' are acceptable synonyms of 'measure' and that the common element in the definitions is 'comparison.'

In workaday science the comparison is with a numbered scale, and results are expressed by number and name, as 'three inches,' '65 degrees,' '43 years 6 months.' A scale built up by the addition of equal standard units is the ideal, but to say that measurement is possible only by such scales, would seem to be an unhelpful limitation of the meaning of the word. If physics has reached the stage where the ideal can be achieved, it may be desirable to speak of measurement by comparison with its perfect scales as 'physical measurement' while leaving less fortunate sciences to work with their, possibly crude, approximations.

When we turn to actual measurements being made in psychological laboratories we find in use metre scales and foot rules, balances and weights, chronoscopes and stop watches, resistance boxes, galvanometers, photometers and any other measuring instrument that ancient wisdom or modern physics has made available and happens to be of service in the task in hand.

One general group of tasks consists in measuring the results of bodily activity carried out under controlled conditions. Take as an example the product of a person's behaviour when asked to draw lines on blank foolscap paper of length equal to half the width of the paper. In one experiment 2,048 such lines were drawn and measured. It is probable that no two lines were exactly the same length, and that measurement to 0·01 mm. would have proved this, while obscuring a law binding them together.

Choosing a coarser unit, we measure to the nearest millimetre and find 92 lines of 103 mm. length at the modal value of results scattered from 69 to 135 mm. Relative to the material our unit is still fine, so by addition we find the numbers of lines that would have fallen into each group had we measured with units 2, 3, 4, 5 and 6 mm. respectively. With increase of the size of unit the numbers approximate more and more closely to a smooth curve. Further, as we take out the figures for measurement with a unit of 6 mm., we recognise in them an approximation to the terms of the binomial expansion $(1 + 1)^{11}$. Then, using the slightly smaller unit of $5\frac{7}{8}$ mm., we obtain the curve of Fig. 1 with its close approximation to the binomial point curve. For a particular case we have established the fact that by suitable choice of unit our experimental data fall into groups closely approximating to the binomial distribution of their number, 2048. And this is but a particular case of a general law.

The Gaussian continuous function, commonly called the *normal curve* or *curve of error*, in the form

$$y = \frac{N}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}$$

gives close approximations to the values of binomial distributions, and is usually taken to represent the law of distribution of the results of the bodily expression of mental intention. The frequency with which results of this nature

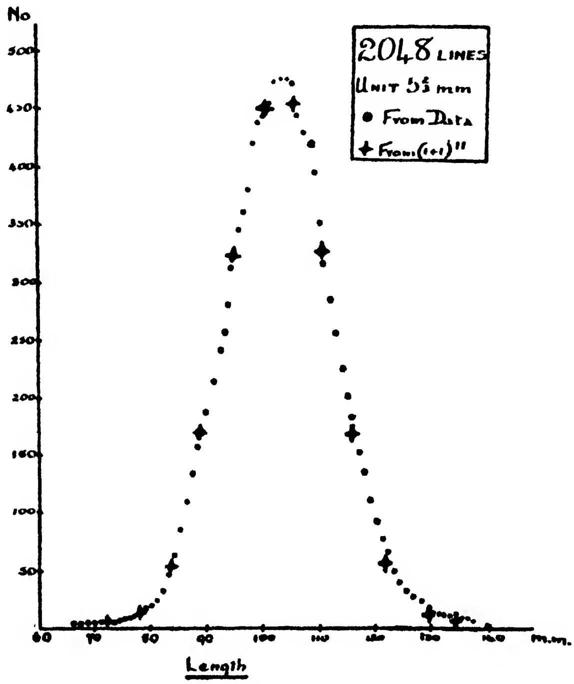


FIG. 1.

are obtained in psychological experiments leads to the conclusion that an appreciable scatter is an essential feature of our data, and that, while the old time physicist or chemist can rest satisfied with the mean of two determinations, we must make at least 50 before we can be reasonably sure of the values of our constants. Experimental psychology could have made little progress without accepting what Dr. Darwin, last year, in his presidential address to Section A, called 'the fuzziness inherent in absolutely all facts of the world,' when he was arguing 'that the subject of probability ought to play an enormously greater part in our mathematical-physical education.' [6]

We have seen that Kant reached the conclusion that mind had but one variable—time. Without accepting his conclusion, we can concur in the importance of the time factor in mental happenings, and appreciate the part played in psychology by the Wheatstone-Hipp Chronoscope, stop watches and

[6] *B.A.A.S. Report*, 1938, pp. 32, 33.

other instruments for measuring and recording time intervals. The human factor with its individual differences forced itself upon the attention of astronomers in 1796, and led to acceptance of the 'personal equation' as a necessary correction to an observer's data. Physiologists became interested and sought in reaction experiments the 'velocity of the nervous impulse.' Later, psychologists took up the study of the duration of simple mental processes. The so-called simple reaction time is the time taken between the giving of a stimulus and the recording of awareness of the resulting sensation. The significance of any difference obtained depends upon the accuracy with which the mean has been obtained and the scatter value of the individual readings. It becomes necessary to consider the use of the probable error.

This measure of scatter became popular in psychology because of its readily remembered relation to the data. Within the limits defined by the probable error half the cases fall. Having determined the probable error of a case as the semi-interquartile range, by counting, or as $0 \cdot 6745\ \sigma$, by calculation, the probable error of the mean is obtained by dividing this by the root of the number of cases, and the probable error of the difference between the means of two different sets of reaction times can be determined by taking the root of the sum of the squares of the probable errors of the two means. The ratio of the actual difference of means to the probable error of that difference is a measure of the significance of the difference.

Starting from comparatively simple beginnings, reaction times of more and more complex mental activities were determined and the chronoscope has become for the psychologist what the balance is for the chemist. The nature of the associative links of memory are linked to differences in the 'association time' and medical psychology has found a useful tool in the stop watch used with the Jung or some other word list. In many experiments, time is the indicator of difference or agreement; but what the differences are due to has to be discovered by introspection and the analysis of records of many introspections obtained under experimental conditions. When the experimenter reaches the stage of being able to prophesy the nature of the introspection not yet disclosed he is justified in accepting the reaction time as an indicator, not only of a difference in experience, but also of the nature of that difference.

Our concern till now has been with the products of mental activity and the duration of experiences. Psychology, however, is concerned more with the nature of the experience than with its effect on the environment or its bare duration, and so the question arises as to whether sense experiences have quantitative characteristics other than duration. The general conclusion is that they have. Ward writes: 'A single sensation we find has not only a determinate quality but it is also quantitatively determined in respect of intensity, protensity (or duration) and extensity.'[7] Titchener speaks of 'intensity, clearness and duration,'[8] and Spearman adds 'speed,' pointing out that 'A man's perception of one and the same black spot may either be clear, intense, quick and persistent, or else the reverse of these. And in this way the total experience in the two cases may become wildly dissimilar. But the objective blackness of the spot remains approximately constant.'[9]

It would seem undeniable that intensity is a characteristic of sensory experi-

[7] *Psychological Principles*, p. 105 (1918).
[8] *Textbook*, p. 52 (1919).
[9] *Psychology down the Ages*, p. 262 (1938).

ence, and for this reason it is, at the least, unfortunate that Stevens and Davis should, quite definitely, have handed it over to physicists as exclusively a property of the thing cognised.[10] In the words of Titchener,[11] 'Intensity is the attribute to which we refer when we say that a given sensation is brighter or duller, louder or fainter, heavier or lighter, stronger or weaker, than another sensation. In making such comparisons, we think of the sensation as possessing the same quality : both are blue, both are *bb*, both are pressure, both are cold or salt or asafœtida : but these two sensations, of the same quality, lie at two different points upon a finite scale of sensation degrees, which begins at a lower limiting value and rises to a maximum. The more intensive sensation is placed higher up, the less intensive lower down, upon the scale of intensities.'

When we attempt to evaluate this quantitative element in sensation we are met with difficulties. First comes the fact, already referred to, that the same material object may be perceived by sensations that vary greatly in intensity. The intensity of experienced sound of an express train is as a rule different for a passenger comfortably sitting in it and for a would-be passenger standing on the platform as it rushes through a station. The intensity of the noise of a ticking clock sinks below the threshold when we are engaged in an absorbing task, but the energy output of the clock remains reasonably constant. The same source of stimulation occasions different intensities of sensation according to the subjective attitude of the recipient of the energy falling upon the sensory organs. To secure consistent results it is necessary to control the conditions, and in experiments involving sensation-intensity this is done by arranging that the subject shall give undivided attention to the stimuli. The maximal intensity thus obtained is accepted as constant for the given stimulus.

Normally we do not discriminate the intensity of the sensation, nor are we interested in the particular sensation itself. Our interest may be in the pleasure tone of the whole sensation complex, as when enjoying music or a glorious bank of flowers, but, more often, our interest is in the properties of the external objects that occasion the experience. The lightning's flash, the trumpet's blare are ominous portents, rather than intense sensations. This preoccupation with the things of the external world has given us science but makes introspective analysis of experience difficult. It endows sound, light and matter with 'intensity' which we proceed to measure with acoumeters, photometers and a balance. For the psychologist, however, these measurements are only of interest so far as they may help to throw light on the problems of sensory experience.

Early in the life of experimental psychology the smallest change in the stimulus value that could be appreciated in sensation became the subject of inquiry and, for the determination of this difference threshold, difference limen, least perceptible difference or just noticeable difference, the psychophysical methods were developed and gave to psychology 'a technique whose wide serviceability does not even yet seem to be fully appreciated.' [12]

Weber, experimenting with weights, reported in 1834 that 'If we are comparing by touch two weights, the one of 30 and the other of 29 half ounces, the difference is not more easily perceived than that between weights of 30 and 29 drachms . . . Since the distinction is not perceived more easily in the former

[10] *Hearing*, p. 110 (1938). [11] *A Textbook of Psychology*, p. 53 (1919).
[12] Spearman, *Psychology down the Ages*, p. 90 (1937).

case than in the latter, it is clear that not the weights of the differences but their ratios are perceived.' [13] In this way was first stated the law that the ratio of the just noticeable difference in the value of the stimulus to the value of the stimulus is, within certain limits, a constant. From the fact that the same law was found to hold for seen lengths of line Wundt passed to the general law—a bold use of inductive method. It was left to Fechner to develop the psycho-physical methods and to put the law on a sound basis. He went further : on the basis of the assumptions that a just noticeable difference of sensation is a quantity of sensation and that all just noticeable differences are equal, he transformed Weber's statement of the facts into a law expressing the relation of sensation-intensity to stimulus quantity in the form that sensation-intensity was proportional to the logarithm of the stimulus value.

The theoretical implications of this law are still matter for dispute. After seven years' discussion some members of the sensory events committee are unable to accept Delbœuf's contention that, while it may be true that sensation-intensity cannot be measured, 'sense-distance' can. On the way to agreement to disagree, however, the committee did valuable work. In addition to securing statements of the grounds on which certain physicists state, and some psychologists agree, that in no reasonable sense can sensation-intensity be measured, they have secured a critical survey of work on sound intensity by Semeonoff of Edinburgh and a summary of work at Cambridge, by Craik and others, on conditions controlling sensation-intensity results.[14]

Interesting work carried out in the physiological laboratory of Cardiff was also reported to the committee. Results obtained there by Gage [15] showed an apparent lack of consistency in the judgments of his subjects that appeared to invalidate much, if not all, results obtained by psycho-physical methods. For a time the position looked serious, although psychologists suspected that some form of 'constant error' was present and responsible for the results. This would seem to be the case, for repetition of the work, by Newman, Volkmann and Stevens [16] at Harvard, under slightly different conditions, gave results consistent among themselves.

The methods used in these experiments depend on the judgment of equality of 'sense-distances' that are supra-liminal. The stimuli corresponding to the sensations limiting the 'sense-distances' are determined by one of the psycho-physical methods, but in view of the nature of the task, it has become customary to speak as if the method of 'equal appearing intervals' or of 'mean gradations' were an independent method. One form of the experiment consists in finding the value of stimulus that causes a sensation judged by the subject to be half-way between sensations caused by two other stimuli, and has been termed the 'method of bisection.' Using this method, Gage found the loudness value of a variable tone that appeared to be half-way between the loudness of two other tones. He then bisected the upper and lower halves respectively, and, having found the stimulus values of the one-quarter and three-quarter 'sense-distances,' proceeded to bisect this one-quarter to three-quarter distance and found that the value so obtained was consistently higher than that given by the original bisection. A possible deduction is that the

[13] Quoted Titchener, *Experimental Psychology, Instructor's Manual, Quantitative*, p. xvi (1905).
[14] *B.A.A.S. Report*, pp. 278–296 (1938).
[15] *Proc. Roy. Soc.*, B, 116, pp. 103–19 (1935).
[16] *Amer. J. Psychol.*, 49, pp. 134–137 (1937).

method is useless and results obtained by it in the past valueless. Another possibility is that we have the cumulative effect of a small positive ' constant error.' The results of Newman, Volkmann and Stevens support the second alternative.

Weber's law appears to be true for a limited range of stimuli only. When we pass out of the zone of sensation to which we are accustomed, our ability to judge of equality becomes subject to an increasing error, and our judgment of difference, as usually determined, includes this error. As a result the ratio of just noticeable difference to stimulus rapidly increases in value as we recede from the central zone. The laws governing this increase became of interest to physicists engaged in work on noise and illumination, and led Sections A and J to hold a joint meeting in York in 1932 and then to collaborate in the work of the Sensory Estimates Committee.

In preparation for that York meeting I carried out a series of experiments on judgment of equality and difference of lifted weights, the most interesting of which were carried out with geometric series of weights. In weight lifting experiments, a subject, having lifted first one weight and then another, passes a judgment of heavier, equal or lighter on the second weight as compared with the first. He compares two past sensation experiences, and it must be on the basis of their values as preserved in memory. Any change that takes place in these memories will affect the first experience more than the second. Constant errors are due to these facts. When two objectively equal weights are lifted, the second weight is consistently judged either heavier or lighter than the first, except over a small range the absolute value of which depends upon the nature of the objects being used. For weights smaller than those of this central zone the second weight seems heavier than the first, while for weights above the zone the second weight seems lighter. In many psycho-physical experiments the effects of such errors are neutralised in order to reach what is known to be objective equality. Thus, if working with weights in cans of such dimensions that a 10 oz. can lifted first is matched with a 12 oz. can lifted second, it will be found that the 10 oz. can lifted second is judged equal to a can of approximately 8 ozs. Taking the mean of 12 oz. and 8 oz. we arrive at the actual weight, 10 ozs., the one ' error ' balancing and cancelling the other. If, however, we work more carefully, we may find that the approximately 8 oz. weight is really $8\frac{1}{3}$ ozs. and the mean becomes $10 \cdot 17$ ozs. Our compensation is not exact : a residual ' error ' remains. An ' error ' of that nature will explain the apparent inconsistency of Gage's results. Weber's law demands that the arithmetic mean of the older sciences be replaced by the geometric mean in psychology.

Returning to our experiments with geometric weight scales : the chief series was composed of flat circular aluminium boxes 4 cm. in diameter and 2 cm. deep, of weight equal to $4\ (1 \cdot 03)^{n-1}$ gms., where n is the series number of the box. Working with a subject who had had experience with other series, it was found that the centre of the zone where he judged equality of weight correctly was box 55 and that this zone was about 30 boxes wide. Below box 40, boxes were matched by boxes objectively heavier, and above box 70, boxes were matched by objectively lighter boxes. Working with one hundred boxes, it was found that the regression was more marked with the lighter weights than with heavier ones. In an attempt to secure as great a difference at the upper end as at the lower the scale was enlarged to 121 members, but the results

were disappointing. The difference obtained on weight 121 was no greater than the difference obtained six days earlier with the then heaviest weight, No. 100. The series was then pushed to the limit possible, which gave weights up to No. 130, but again the increased weights failed to produce an increase in the maximum difference. When, however, the work done on the three different days was distinguished, it was found that the explanation of this apparently unsatisfactory result was that the subject's central zone was steadily gaining towards the heavy end while it remained fairly constant at the lighter end. The results are given in diagram form in Fig. 2. It will be seen that the figures of the second and third day respectively give the same general trend as those of the first day but shifted along the horizontal axis. The curve of the

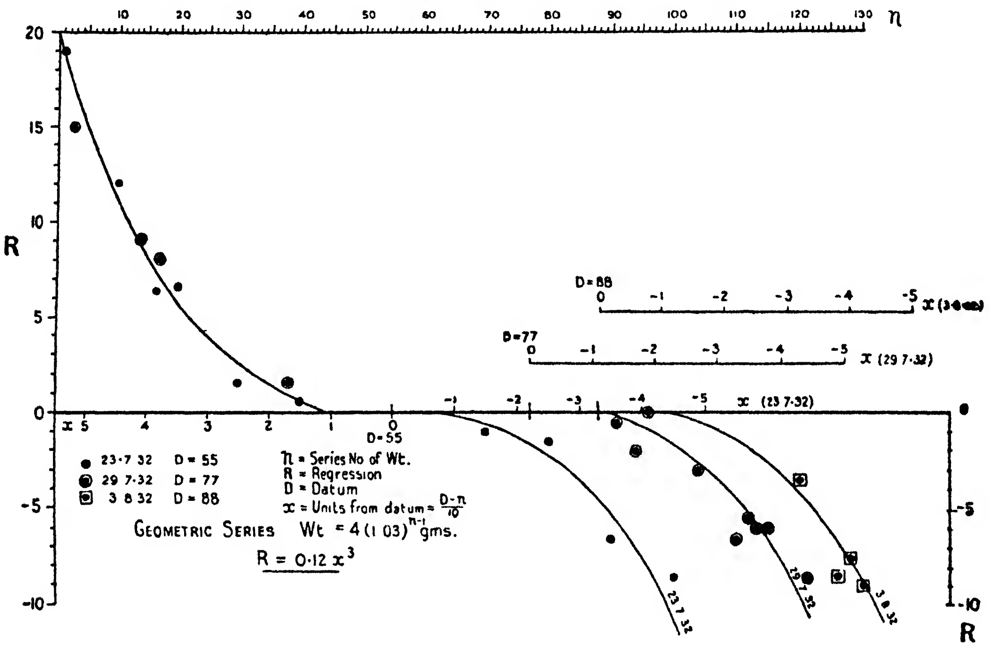


Fig. 2.

first day balances about weight 55 and the heavier end curves for the second and third days are similarly related to weights 77 and 88. The curves suggest a cubic increase in the regression, reasonably well expressed by $R = 0{\cdot}12x^3$, where $x = \frac{D - n}{10}$ and D is the datum value, 55 for the first day and 77 and 88 for the higher values on the second and third days.

One method we used separated the weights, when compared with a selected one of their number, into weights heavier, lighter and equal. The size of the zone of equality is a measure of the sensitivity at that part of the scale, and as the scale is a geometric one, equality in the size of this zone at various parts of the scale would mean agreement with Weber's law. We found that the zone of equality was largest at the light end of the scale and slowly decreased in value as the scale is ascended. Judgment is most difficult at the lower end and easiest at the upper end. To reckon the difference from the best equal value

instead of from the standard stimulus value is in accord with the subjective sensory basis of the judgment. The scatter error on equal judgments, not the constant error, is a measure of sensitivity. But, if the scatter and constant errors are combined, the result will appear as a rapid increase in the value of the Weber ratio as we pass away from the central zone to which we are adapted.

Most, if not all, the work on the variability of the Weber constant has been on crude threshold values composed of the constant error and scatter error. The law was criticised very early and, from various possible tables of figures, consider those of Biedermann and Löwit [17] for pressure. Expressing the ratio as a decimal, instead of a vulgar fraction as was common in the early days, we obtain the table below.

Pressure.

Absolute weight W grams.	Just noticeable difference Δ W grams.	Ratio $\frac{\Delta W}{W}$.
10	0·7	0·0700
50	1·7	0·0340
100	2·4	0·0240
200	3·6	0·0180
300	4·6	0·0153
400	5·2	0·0130
450	6·5	0·0144
500	25·5	0·0510

Plotting the ratio against the weight, we obtain Fig. 3, in which, instead of a straight line parallel to the weight axis, a roughly U-shaped curve is given; from which can be deduced, for this particular experiment, that there is an approximation to Weber's Law for weights between 100 and 450 grams, but that above and below the 'quotient of sensitivity' rapidly increases in value. Such curves are scattered throughout the voluminous literature on the subject, the stimulus scale, however, being the logarithm of the stimulus value. Several of these are given in Selig Hecht's contribution to Murchison's *Foundations of Experimental Psychology.*[18] In his diagram for illumination intensity,[19] founded on work from 1865 to 1918, the left limb of the curve resembles the curves of Fig. 2, and reading from the curve values of $\frac{\Delta I}{I}$ and log I, cubing the second and multiplying the first by 120, we obtain the table on page 432.

We conclude that underlying the whole controversy is the fact that the experiments have measured, not the sensitivity of sensory discrimination, but rather the 'constant error' due to regression of the memory image of the first stimulus towards the values of the central zone of adaptation.

[17] See Ladd, *Physiological Psychology*, p. 368 (1896).
[18] Pp. 216–72. [19] P. 246.

Much work has been done on bodily and mental work, and results obtained have found direct application in industry. We cannot now deal with the way in

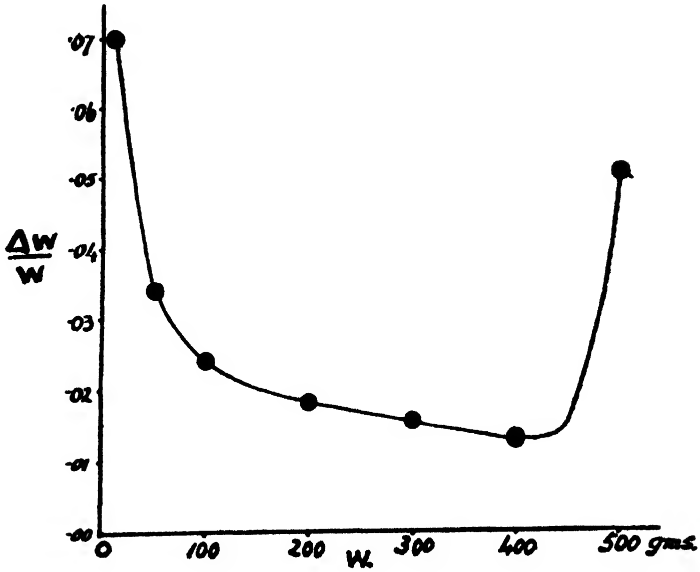


Fig. 3.

which measurement enters into this work, but must spare a moment to call attention to extremely interesting theoretical matters that arise from the work

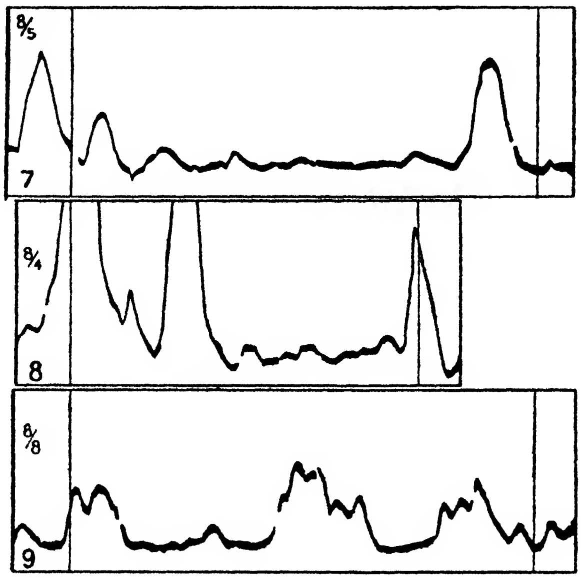
Illumination Intensity.

$\frac{\Delta I}{I}$	log I (millilamberts).	$(\log I)^3$ (to nearest unit).	$\frac{\Delta I}{I} \times 120$
0·7	4·4	85	84
0·6	4·2	74	72
0·5	3·9	59	60
0·4	3·6	47	48
0·3	3·3	36	36
0·2	2·9	24	24
0·1	2·3	12	12

of our Recorder, who finds, in the fluctuations always recorded in work curves, the sum of a number of geometric waves, all having a common factor in their periodicity and commencing at a common datum.[20]

[20] S. J. F. Philpott, *Fluctuations in Human Output. Brit. Psych. Soc. Monograph*, VI, 17 (1932). *A Theoretical Curve of Fluctuation of Attention. Brit. J. Psychol.*, 25, p. 221 (1934).

Another branch of experimental psychology busies itself with the physiological concomitants of emotional experience. On a smoked drum record of a subject's breathing, measurement can be made of frequency and amplitude, and changes therein can be compared with introspection records to find out their meaning. The inspiration-expiration ratio, with varying emotional states, shows marked variations from the average value, rising to as much as three times that value in ' amazement ' and sinking to about half the value under the sense of guilt or shame awakened by conscious misrepresentation or wilful falsehood. These changes in the ratio of inspiration to expiration are



Scale ⅓.

FIG. 4. TACHOGRAM RECORDS FROM

7. A Hopeless Dawn........Frank Bramley, A.R.A.
8. Two Strings to her Bow........John Pettie, R.A.
9. Renunciation.............P. H. Calderon, R.A.

accompanied by marked changes in frequency, amplitude and form, which result in characteristic curves that the eye can read and interpret without recourse to the millimetre scale and time record. The whole profile, rather than its analysis, is diagnostic.

A sensitive physiological concomitant brings about the fall in resistance that is commonly called the psychogalvanic reflex. In Fig. 4 we have curves traced by light from a mirror galvanometer on photographic paper as a record of the changes in the secondary current of a transformer, the primary coils of which were in a circuit in which current changes were occasioned by variations in the resistance of the subject's hand when looking at a series of pictures. It would be possible to convert the curves into electro-dynamic units of energy, but such refinement is unnecessary and, at present, would be of little practical value. The energy is proportional to the area enclosed between the curve and baseline and the relative values of its amount correspond with the relative values of the emotional-conational content of the experience. The changes in

outline correspond to introspected changes in experience and, with the subject who gave these records, differences in the shapes of the curves are diagnostic.

On the basis of such records it is possible to grade pictures in emotional value. Taking the records for a number of subjects and dividing the records into three grades it was found possible to break the pictures into seven groups, and selecting, from the centre of such groups, pictures that had a small scatter value we were able to secure a scale of values similar to scales which we shall see are playing a great part in more recent work. Instead, however, of resting wholly upon mental estimates our scale has the objective records of physiological changes as a basis.

An entirely different method of measurement had by 1920 reached the stage where it could not be ignored. Intelligence tests were being widely used, and the Board of Education set up a consultative committee to report 'on psychological tests of educable capacity and their possible use in the public system of education.' The Report appeared in 1924, and the principal findings of the committee were : 'That up to the present the only kinds of psychological tests of educable capacity that have been sufficiently developed to be of much service in schools for the purpose of diagnosing and assessing such capacity are tests of 'intelligence,' standardised scholastic tests, and to a less extent vocational tests.' [21] Let us consider the first of these.

In 1883 Galton [22] formulated the possibility of measuring intellectual abilities by laboratory tests. In 1890 Cattell [23] was writing on the subject and in 1896 he published the result of physical and mental measurements of the students of Columbia University.[24] In 1904 Spearman wrote on 'general intelligence objectively determined and measured,' [25] and in 1905 Binet published several articles on new methods of diagnosis of the intellectual level.[26] In the next fifteen years the measuring of intelligence by tests established itself in Europe and America.

The foundations of the method are laid in Binet's happy thought of 'mental age' and Spearman's application of methods of correlation to psychological data. Prior to Binet's work testing had been confined almost entirely to tests of sensory discrimination. Spearman proceeded to calculate correlation coefficients between the results of such tests and estimates of intellectual ability. Binet 'instead of measuring the intensity of simple faculties' set out by tests 'manifold and heterogeneous . . . (to) measure acts of adaptation . . . to determine how many years an individual is advanced or retarded.' [27] His measure is a time measure based on the normal development of intellectual ability. Originally his 'manifold and heterogeneous' tests were 54 in number, used for the diagnosis of mental deficiency. This number has steadily increased until, in the New Revision of the Stanford-Binet Scale, issued by Terman and Merrill in 1937, there are two sets of 129 tests each, covering mental ages from 2 years to 22 years 10 months and providing for I.Q. values up to 170 for children and up to 152 for adults.

By correlation methods, Spearman compared the results of tests of sensory

[21] Board of Education, *Psychological Tests of Educable Capacity*, p. 136 (1924).
[22] *Enquiries into Human Faculty and its Development* (1883).
[23] *Mind*, XV, 9, p. 373 (1890).
[24] *Psychol. Rev.*, pp. 618–48 (1896).
[25] *Amer. J. Psychol.*, XV, 274 (1904).
[26] *L'Année Psych.*, 11, pp. 163–336 (1905).
[27] *Psychological Tests of Educable Capacity*, p. 24 f.

discrimination and estimates of intellectual ability, inaugurating a new phase of mathematical activity in psychology, in which, again, the tasks led to new methods. Often, when we lack a scale wherewith to measure, it is possible to arrange persons or things in order of merit. To deal with such 'rankings' of estimates, Spearman [28] transformed the Pearson-Bravais expression $\frac{\Sigma(xy)}{\sqrt{\Sigma(x^2)\,\Sigma(y^2)}}$, where x and y are deviations from mean values, into the expression $1 - \frac{6\Sigma(d^2)}{n(n^2-1)}$, where d is the difference in the ranks given to the individual for the two abilities or other characteristics.

The correlation between two sets of measurements or rankings is a measure of the extent to which the sets of figures agree, and this agreement would seem to be due to a common factor in the abilities measured. It follows that 'when any pair of abilities are to any extent correlated with each other, to this extent *they can be regarded as depending upon a common factor*. . . . Otherwise expressed, each of the abilities may be taken to involve two factors, the one common to both, the other specific to that ability alone.' [29] Extending this thought to more than two abilities, Spearman developed his theory of two factors, and evolved various criteria for establishing the existence of the relations that fit the theory, culminating with the tetrad equation, $r_{ap}r_{bq} - r_{bp}r_{aq} = 0$, and its probable error.

The final proof of this criterion rests upon Yule's formula for partial correlation, on which a word should be said. In psychological experiment, it is usually impossible to secure conditions free from all sources of variation other than those we wish to study. Partial correlation gives the means of eliminating the effects of disturbing influences by the calculation of what the correlation between two variables would have been if other variables had been constant.

The common factor of the two abilities becomes the 'general factor' of the many. There emerged 'the concept of a hypothetical *general* and purely *quantitative* factor underlying all cognitive performances of every kind.' [30] This has been equated with 'general intelligence' and labelled g. It is an innate capacity to acquire abilities to varying degrees. Its measured value enables children to be divided according to capacity to profit by education and adults according to the kinds of work for which they are fitted. Such a classification was given by Burt in his presidential address at Liverpool, in 1923.[31]

The method that gave g would equally well give other general or group factors if tests were found that gave correlations obeying the tetrad law and independent of g. Some of such factors are a general character-factor (w), perseveration (p), and oscillation (o), which were isolated by Webb, Wynn Jones and Flugel, respectively.

Soon, however, the difficulty of securing that freedom from 'overlap' which is demanded by the Spearman technique led to the development of methods of analysing tables of correlations in which there are factors that are common to a number of the tests. These are the methods of Factor Analysis,

[28] *Amer. J. Psychol.*, XV, p. 274 (1904).
[29] Spearman, *Abilities of Man*, appendix, p. i (1927).
[30] Spearman, *The Nature of 'Intelligence,'* p. 5.
[31] *B.A.A.S. Report*, p. 227 (1923).

the exact value and meaning of which are still matter of debate. The record of a symposium of the British Psychological Society on the subject is appearing shortly in the Society's *Journal*.

In all this correlational work it is needful to know the reliability that can be placed on the data, whether obtained by measurement or estimate, and whether the correlations have significant value. Methods for dealing with these problems are available. Also a growing use is being made of Fisher's [32] development of Pearson's χ^2 test of significance, while an interesting development of the use of rankings is that of Kendall's [33] 'new measure of rank correlation.'

The 1924 Educable Capacity Report gave limited approval to vocational tests but concluded that 'the range of such tests (was) not yet sufficient for any recommendation.' [34] The Medical Research Council through the Industrial Fatigue Research Board had been busy with the problem for some years, and in 1922 this Board, in co-operation with the National Institute of Industrial Psychology, undertook a preliminary investigation into the possibilities of vocational guidance. The group of psychologists who, under the leadership of Prof. Burt, carried out the investigation reported in 1926.[35] The research had shown that both stability of employment and satisfaction are greater amongst those who had obtained employment in keeping with the recommendations made on the basis of the test results, than amongst those in other employment, and that it would seem true that the methods used 'will prove of the utmost value to the individual and to the community, to the employer and to industry as a whole.' [36]

More important, however, for our purpose, is that portion of Burt's conclusions which deals with the limitations of the tests. He wrote : 'It is clear that tests can cover no more than a limited part of the field. However perfect, however carefully standardised, tests by themselves mean nothing. To apply a scale of intelligence tests, and to read off the result in a single formula—a mental age or mental ratio—is but the beginning, never the end, of a vocational examination. . . . With almost every test and with almost every child, the real value of such method lies . . . in the interpretation of the test results . . . tests should be corroborated by personal observations ; many factors of the utmost importance in choosing a vocation are, in the present state of knowledge, not amenable to direct measurement by any of the tests hitherto devised. Of these additional factors, the most important appear to be qualities of temperament and character. Such qualities are more essential for industrial life than they are for progress in school work. It is, therefore, eminently desirable that suitable tests for such qualities should, if possible, be devised.' [37]

Since 1926 much work has been done on vocational guidance, both by the Board, under its new title of Industrial Health Research Board, and by the National Institute of Industrial Psychology. As a result of investigations carried out by these bodies and many individual research workers, in this and other countries, tests for abilities and skills of value in industry, and for particular disabilities that unfit for certain occupations, are available and are being used with increasing frequency. Much progress has also been made with the

[32] *Statistical Methods for Research Workers*, 7th Ed. (1938).
[33] *Biometrika*, XXX, I and II, pp. 81–93 (1938). [34] P. 143.
[35] I.F.R.B. 33, *A Study in Vocational Guidance* (1926).
[36] Report 33, p. 102. [37] Report 33, p. 100 f.

measurement of temperament and character, a valuable summary of which will be found in Report No. 83 of the Board.

In this report, Vernon reaches the conclusion that, while tests to measure attitudes or interests have not the objectivity and accuracy achieved by tests for abilities, and character and temperament traits present even greater difficulties, good progress has been made, and, with a better understanding of the methods and meaning of the results of factor analysis, ' we may hope before long to achieve a fairly complete classification of all our psychological measuring instruments which would be of the utmost value in many branches of pure and of applied psychology.' [38]

The order of progress has been : the measurement of intelligence ; the measurement of special abilities and skills ; the measurement of attitudes and interests ; the measurement of temperament and character traits. To deal with the growing complexity of the material, mathematical theory and technique have been developed until sometimes there seems danger of losing the facts in the figures, and it becomes necessary to remind ourselves that mathematical analysis cannot confer value on valueless data. The methods by which the data are collected are of prime importance. In the earliest work the instruments used were the ordinary scales of physical science ; what a man did or judged was submitted to measurement in millimetres, grams, foot candles, pitch, thousandths of a second, ohms. Physical measurement was possible, and, too often, was equated to the mental experience.

When physical measurement is impossible we may be able to secure rankings. Most people can arrange colours, pictures, persons, poems or holiday resorts in an order of preference. Consider the case of colour preferences. In sorting a set of fifty or more colours twice there will, as a rule, be considerable difference in rank of some of the colours, even if the second sorting be made immediately after the first. The greatest changes are with items towards the centre of the list, while the items nearest each end often retain their original ranks. Classification in rank presents greater difficulty with medium, than with extreme, values. To determine the value of the lists, we calculate the correlation between the two rankings. This gives the ' reliability ' (or ' consistency ') coefficient for the subject-task. From an important angle this coefficient is a measure of the reasonableness of the task.

Preference orders vary, sometimes greatly, from person to person. As a result we may find that, for a group of subjects, no item is consistently first or last. The variability of rank of the centre of the individual records has extended to the ends, and we may find, for sixteen colours, that the average rank of the colour most preferred is say, 3·6 and the least preferred, 11·9, while some colours have a very wide scatter value. If all the colours gave so high a scatter that it appeared that colour preference was completely specific, the average rank of each item would work out at a value equal to half the number of items. Thus the difference between the average ranks of the least preferred and most preferred is a measure of the magnitude of the common factor.

The rank order of the average ranks of the colours may be taken as a

[38] P. E. Vernon, *The Assessment of Psychological Qualities by Verbal Methods*, I.H.R.B. Report, No. 83, pp. 103–10 (1938).

norm of colour preference for the group. We can then calculate the correlation coefficient of any individual ranking with this norm and secure a measure of the normality of the particular subject. Of much greater interest, however, is the nature of the variations from the norm and any tendency there may be for subjects to fall into groups exhibiting similar variations. Determining the correlations between the various individual rankings, we can separate them into groups having high intercorrelations and then proceed to discover reasons for the agreements and differences. We may go further and, selecting groups in which the tetrad condition is satisfied, evaluate the amount of the common factor in each member of the group. The common factors of any two such groups will probably have something in common—a broad, more general, factor. Correlation of individual rankings with this more general factor will be lower than with the common factor of a group, and to that extent it is a measure of likeness to the common average rather than to the more valuable characteristic variation. Alternatively, we may submit the whole table of correlations to factor analysis and express each ranking as the sum of some four or five factors which may, or may not, have ascertainable meaning in relation to the subject's experience of the colours.

As the norms and the correlations rest on the rankings, it seems desirable that the rankings should be as accurate as possible and for that reason the method of paired comparisons was evolved. In this method, each item is compared with each other item. The preferred item in each comparison is credited with one mark, unless the items appear equal, when each is given half a mark. The order of preference is the order of marks obtained. The method is undoubtedly the best for determining the order of a few items, but when the number exceeds, say, twenty, it is best to make a rough ranking, or grading, first and then to take overlapping groups of, say, ten items and carry out the paired comparison technique on successive groups. It would seem, however, that for large numbers the method has little advantage over the rougher, ranking technique.

We have seen that the difficulty of securing consistent ranking at the central values is great. Often a subject will say it is impossible to distinguish any difference, and he accepts, with relief, permission to group together two or more of equal value. He is still happier if bidden to replace a ranking method by a grading one. Let him divide his material into a few groups that appear to him to represent equal steps of the quality he is judging and we can then evaluate the results by the Pearson-Bravais formula on the assumption that our grades are equivalent to measurements.

In 1926 [39] I reported to the Section a method of grading that had been evolved in dealing with the judgment of value of advertisements. In this ' method of fractionation ' groups are successively subdivided into three sub-groups. To divide material into seven grades, we divide into three groups and number them 2, 4, 6, then divide each into three, numbering them 1-2-3, 3-4-5, 5-6-7. Coupling up the two threes and two fives, we obtain seven grades. If the material is a fair sample, taken at random, it will be found that there is a marked tendency towards binomial scatter. If we secure judgments on, say, the relative attention-catching power of a large number of advertisements from a number of judges we can cut our material up into

[39] *B.A.A.S. Report*, 1926, p. 401. *J. Nat. Inst. Ind. Psych.* III, 5, pp. 252–63 (1927).

seven or more groups. Then, selecting from each group specimens which are central for the group and have a small scatter value, we can build up a scale by which we can evaluate other advertisements. In this evaluation the judge is not asked to give his own opinion of the advertisement, he is asked simply to compare it with the scale.

In one case, four practised subjects compared 417 advertisements of a particular firm with a scale of seven grades, showing half grades, prepared from the whole of the advertisements in a week's issue of the *Daily Mail*. The averages of the four evaluations gave subdivision to eighths of a grade. Plotting the number of advertisements falling in grade blocks centring at each eighth

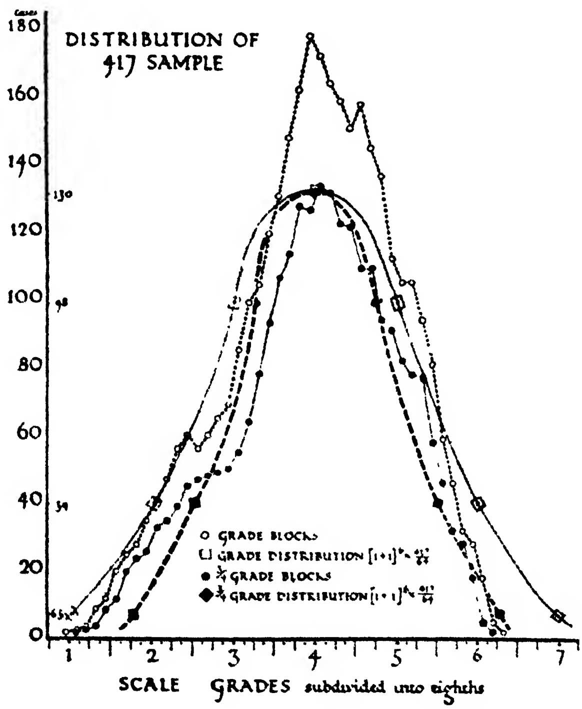


FIG. 5.

in the scatter a result was obtained as in Fig. 5. There is an approximation to binomial scatter. The material, however, is more homogeneous than that from which the scale was prepared and the curve rises above the binomial curve and shows a smaller scatter. Returning to the data and calculating the size of ¾ grade blocks a second curve is obtained. This gives a very close approximation to the binomial curve plotted on this smaller base.

A similar technique has been applied in the preparation of attitude scales such as Thurstone and Chave's *Attitude to the Church Scale*.[40] From 130 statements about the church, on the basis of the opinions of 300 judges who divided the material into 11 grades, 45 statements which had relatively small scatter values were selected. These 45 items, instead of being chosen, as in our

[40] *The Measurement of Attitude* (1929).

scales, to fall at the scale and half-scale numbers, were chosen without any reference to the actual scale values except that they should be spread fairly evenly over the entire range. Their median values, as 3·6, 7·1, were taken as their scale values. To use the scale, the person whose attitude towards the church we wish to measure is asked to check those statements with which he agrees, and the mean or median value of his range of choice is taken as the measure of his attitude. Our own experience confirms Ferguson's [41] conclusion that the large number of judges employed by Thurstone is unnecessary, as the personal attitude of the judges towards the statement influences the results little if at all. There is a very high agreement amongst judges of very different personal attitudes as to what is favourable or unfavourable to a particular thesis. Ferguson found that reliable values could be derived from the work of twenty-five judges.

We pass next from attitudes towards persons and things to the question of personality characteristics. Here, as a rule, the scale that we use is completely subjective, the judges' opinions of the extent to which the characteristic is present being expressed in some recordable form. The judge may decide that his own or another's ' adaptability ' is Poor, Fair, Good, Very Good or Excellent, and these classes may be turned into numbers 1 to 5. He may class a person as Schizophrene, Schizoid, Schizothyme, Neutral, Cyclothyme, Cycloid, Cyclophrene. He may rank persons by the usual techniques in order of merit or assess value by giving marks up to 10 or 20. He may approximate to an objective standard by the so-called ' Man to Man ' scales, in which two persons are selected as exhibiting the trait in extremely high and extremely low form, respectively. Then a person is chosen that falls half-way between the extremes and then two others half-way between the central person and the extremes. We have thus a scale of five reference values, secured by a method similar to the psycho-physical method of equal appearing intervals. In using such a scale we shall find that many of those we wish to judge fall between two of the scale values and, as with a transit instrument or other reading, we find ourselves estimating halves and quarters and, with increased practice, tenths. Or again, we may objectify the distance between the scale items as lines and mark the point on the line that corresponds to the position taken by the person in the mental scale. It will be remembered that at the York joint discussion Dr. Richardson used such a *Graphic Scale* to secure estimates of relation of a particular colour to two others by a method of *un*equal appearing intervals.

Instead of the five or more subjectively evenly placed grades, we may resort to the Thurstone technique and secure equivalent-unit rating scales of fifty or more items, each item being a statement that can be made about the characteristic, carefully selected and scoring its median grade. Somewhat similar are the Social Maturity scales, in which a number of statements about the common activities of children and adults are marked with the normal age of acquisition of the ability. By their use a Social Age and Social Quotient are secured in the same way as the Mental Age and Intelligence Quotient.[42]

When a number of characteristics have been rated they may be brought

[41] *J. Soc. Psych.*, 6, 115 (1935).

[42] K. M. B. Bridges, *Social and Emotional Development of the Pre-School Child* (1931). E. A. Doll, *The Vineland Social Maturity Scale* (1936).

together graphically in the form of a profile, and such profiles have been found of great value in vocational selection and guidance. Instead, however, of measuring a number of individual characteristics and then bringing them together in a profile we may rank or grade the various characteristics among themselves for a particular person, and compare that person with another by calculating the correlation between the rankings or gradings of their respective characteristics. Further, if we assume normal scatter and throw each individual set of traits into identically sized groups balanced about the central value, we can calculate the correlation by the very simple formula,

$$r = 1 - \frac{\Sigma\,(X - Y)^2}{K}$$

where X and Y are the actual grade values given to the various items and K a constant equal to half the possible maximum value of $\Sigma\,(X - Y)^2$. The method of correlating persons had been used for some years without its essential difference from correlation of tests being clearly stated. It is to the credit of Stephenson that in his papers on 'The Inverted Factor Technique'[43] he has defined these differences and drawn attention to the advantages of the method.

We have sampled the methods and results of experimental psychology and trust that the sample is a fair one, though possibly somewhat overloaded with ancient history that has become of interest to physicists in contact with the human factor. The sample is statistically inadequate, but has, we hope, enabled the mind to perform its accustomed trick of reaching conclusions from cues or data logically and mathematically altogether insufficient. We have seen psychologists using physical measurements and developing methods of dealing with the new forms of data so obtained. We have seen them following intuitive perception in the belief that their material had quantitative elements not at present amenable to the measurements of the physicist, replacing the scales of physics by estimates, ranking, grading and rating scales and developing mathematics to deal with these new data. We have seen them progressing step by step into more and more difficult fields of inquiry, and may look forward with confidence to yet greater achievements. In these circumstances does it matter much if some continue to believe, with Malebranche, Leibniz and Kant, that our data contain nothing 'that can properly be called measurements' and that it is presumption for us to think that, in any reasonable sense, our data, theories, methods and results constitute 'a systematic science'? After all there is a sense in which logical and mathematical proofs are what the psychology of advertising has called 'rationalisation copy.' Scientific insight, as everyday perception, has ever run ahead of measurement and mathematical proof.

[43] *Brit. J. Psychol.*, 26, 344 (1936) : *J. Ed. Psychol.*, 27, 353 (1936). *Brit. J. Psychol.*, 30, 19 (1939).

SECTION J.—PSYCHOLOGY

COMMUNICATIONS

Session on Films.

Mr. A. Mackay.—Films in schools.

Of all classroom aids to education the most forceful in its appeal to children is undoubtedly the cinema. The innate love of the child for the dynamic rather than the static was more completely satisfied when the still picture came to life. It is in the field of motion and activity that the cinema has its greatest educational value.

The widespread impression, that the viewing of motion pictures induces in children a habit of passive reception inimical to active thinking, has been proved erroneous by experimental work in this country and in the United States. In an American experiment, where a film group was tested against a non-film control group, the film group excelled the control group by a larger margin on the eduction items than on the rote items, and this result was even more pronounced in the retentivity tests. A notable conclusion drawn from many experiments is that in film-taught classes the relative gain of the lower intelligence groups is higher than that of the higher intelligence groups.

For children who, owing to social circumstances, lead lives of circumscribed experience, the cinema is indispensable, for it enriches experience by enabling pupils to view scenes and activities otherwise difficult or impossible to present in the classroom.

Dr. W. B. Inglis.—Children and entertainment films.

Changing techniques and content, variations from one country to another in laws governing censorship and the admission of children to cinemas, the lack of adequate psychological measurements of personality and temperament render it impossible to make valid generalisations concerning the effects of the entertainment film on children.

Three main methods have been used in investigating this topic. These are : (1) questionnaires dealing with such subjects as frequency of attendance at cinemas and film preferences ; (2) laboratory investigation exemplified in studies using the psycho-galvanometer and the hypnograph ; (3) the examination of cases in child guidance clinics. The results have been supplemented by the application of general psychological principles to the problems.

The relevance of the data thus obtained may be seen in discussing such topics of popular controversy as the relation between the cinema and anti-social conduct, the effects of terror films, the alleged failure to distinguish phantasy and reality resulting from frequent attendance at cinemas.

The vices of the entertainment film for children tend to be emphasised to the neglect of their virtues.

Mr. A. Cavalcanti.—Propaganda by films.

Entertainment films, which comprise the bulk of the films seen, are full of implicit propaganda in favour of riches, good luck, social and personal success. They present a picture of the world from which all reference to fundamental economic and political questions is deliberately omitted.

Newsreels present facts, but the emphasis is not on what is socially important, but on what is sensational or amusing or disturbing or impressive to the popular mind. In this they follow the press. Moreover the influence of the press introduces the element of political propaganda, which militates against the disinterested presentation of fact.

Propaganda films are, so far, a very small proportion of the total number of films produced. In the totalitarian countries films are made and shown in order to increase the prestige of the regime, and also for educational purposes. Large amounts of money are available for their production. In the democratic countries, the sums devoted to film propaganda are very small. In this country, most of the money is provided by commercial or industrial sponsors. Sponsorship imposes certain limitations, but it does not prevent good work being done. In spite of it, the individual film-worker remains to a considerable extent free to engage in social education.

Under democracy, the individual is permitted to consider and report facts around him with a free mind, emphasising what he feels to be most important. It is for this reason that democratic propaganda films are always stating social problems while totalitarian propaganda films are always staging parades.

Democratic people believe in the statement of truth for its own sake, holding this to be the first condition of good government.

Mr. Oliver Bell.—Public tastes and the entertainment film.

In forty years the film has developed from a fair ground side-show to a major industry catering for the entertainment of 220,000,000 of people in the world each week. The combined effect of the comfort of the cinema theatre, the psychological effect of looking at a brightened screen in a darkened theatre, the emotional rather than intellectual appeal of the films and the varying motives which lead patrons to pay to enter, dull film-goers' critical senses and render difficult the assessment of public taste. Furthermore, this immense industry has been built up by showmen and conforms to their standards. By unscientific intuitive methods they have roughly assessed public taste and made sufficient profits.

How little the producers really know of public taste is shown by the manner in which each financially successful film is followed by a spate of imitations. No determined effort seems to have been made to discover the psychological effects of the visual realism obtainable through no other medium, since the theatre is artificial and books are just words. The prime necessity of the moment is the creation of a Market Research Board working in co-operation with bodies like the Film Institute, reflecting the attitude of serious film-goers, and the relevant Government Departments and which will co-ordinate to their mutual advantage the conflicting viewpoints of producers, renters and exhibitors, and equate on a scientific basis the demands of the public with the financial, technical and artistic resources of the industry.

Mr. P. Smith.—Selection of skilled engineering workers.

Considerable research work has been undertaken to assess the value of psychological tests in giving vocational guidance to children leaving school. The Birmingham Education Committee has been closely associated with these investigations during the past twelve years, and has published four reports. One of the experiments was designed to investigate the possibility of using psychological tests in the selection of boys for apprenticeship to skilled engineering. This enquiry centred round a junior technical school to which boys are admitted at the age of about 13 plus for a two-year course. Evidence was obtained that aptitude tests applied to boys on admission were more prognostic of success in the school course than was the ordinary academic entrance examination.

The essential criterion of the value of the tests was the boys' success in engineering and allied occupations and the boys leaving the Technical School were 'followed-up' in their industrial careers. It was found that success in the test battery was

more indicative of success in engineering and allied occupations than was success in the academic examination.

The recent publication of the Spens Report emphasises the need for improved methods of selecting boys fitted for admission to Technical High Schools. The Birmingham research work should be of great value to Local Education Authorities in this connection as well as of importance in the field of vocational guidance.

Dr. N. A. B. Wilson.—A survey of a vocational adviser's case book.

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Miss Isabel J. Blain.—Analysis of industrial skill by motion study.

In an attempt to discover specifically what movements characterise skill in industrial assembly, film records were made of electric meter assemblers at work. These records showed performances in comparable pairs, as follows : (1) work of one operator on the same job at two stages in her learning process ; (2) work of two operators doing identical jobs, but having different degrees of efficiency.

Detailed analysis of the films in terms of therbligs (i.e. elements of movements required by industrial operations) revealed that certain movements were quicker in the better performances, while other movements occupied about the same time wherever they occurred. ' Assembling ' movements exemplify the former class, and ' transporting,' ' grasping ' and ' positioning ' the latter. ' Using ' actually occupied a higher proportion of total time in instances of greater skill. There tended to be fewer therbligs in the more skilled examples of performance. ' Positioning,' ' assembling,' ' using,' ' holding ' and ' transporting,' where they occurred at all in an operation, each generally occupied from 20 to 35 per cent. of the total time required for that operation.

Observation of the finer characteristics of different kinds of movements gave rise to certain tentative conclusions regarding the effects of experience and training, and suggested guides for future practice. ' Holding,' for example, proved less passive than has been supposed, and the theoretical perfection of absolutely symmetrical and simultaneous movements may be questioned. There was some indication that the most significant characteristics of skill do not all lie in the grosser motor components, but some, probably, in cognitive and kinæsthetic elements.

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Miss M. M. Mellis.—A study of the sorting process in laundries.

General description of what is involved in this operation, which is the starting-point of the laundry processes within the factory. The various checking and identification systems commonly used in the industry.

Summary of the results of time-studies of the sorting process. How these show the predominating elements of the work and certain technical features. Sorting is seen to be rather different from ordinary industrial operations in that the requirements for successful work are mainly mental ones, such as good powers of attention and discrimination.

Discussion of individual difference in sorting efficiency and their consequent bearing on selection tests, training, control and incentives.

Tests for sorters—how they were devised and how they can be used.

* * *

Prof. K. Koffka.—The ego in his world.

Human behaviour is action of a person in a world. We can understand it only if we understand the Ego-environment relationship. To illuminate this relationship

different types of behaviour will be compared : our own with that of more primitive peoples and of patients with brain injuries. The behaviour of the two last classes, though by no means identical, presents several similar features, like concreteness and lack of spontaneity, which throw light on our own behaviour.

Psychology can accept neither the Ego nor its environment as unexplainable ultimates. The attempt must be made to understand both as creations of the organism. In such a theory Ego and environment develop in close interdependence, and the different types of behaviour previously discussed appear as the outcome of different forms of Ego-environment organisation, different with regard to the Ego, the environment, and the relation between them ; such different forms of organisation must lead to characteristically different forms of action.

Prof. J. Murphy.—The primitive character of poetic genius.

The salient characteristic of all genius is imagination ; and it is particularly the quality of poetic genius. Imagination is a more primitive power of the mind than, say, the capacity for abstract or conceptual thought. The poet precedes the philosopher in history, as the primitive and tribal mind comes before the civilised. The primitive mind is ' perceptual rather than conceptual ' ; hence words which were images from perception and from the concrete preceded abstract terms, and primitive language is highly metaphorical. The earliest literature is poetry. We note the poet's use of image and metaphor in modern times, his delight in wild nature, his ' poetic observation.' The child, the poet and the primitive.

* * *

Dr. P. E. Vernon.—Predicting the psychological aptitude of university and training college students.

The marks of over one thousand students in psychology, and in other subjects studied at a training college for teachers, were compared with scores on intelligence, and other mental tests. Factor analysis of the marks gives clear evidence of a general educational ability factor (which is largely independent of the *g* measured by intelligence tests), and additional group or multiple factors of scientific ability, literary-humanistic ability, and practical ability. Non-verbal group tests give moderate correlations with scientific ability, verbal tests with literary ability ; neither correlate appreciably with practical ability. Psychology marks are best predicted by a combination of the two types of test. With one group of students a correlation of $+ 0\cdot535 \pm 0\cdot032$ was obtained.

Promising results were also obtained with tests of adult reading ability, with certain educational tests such as scientific vocabulary, and with personality and interest questionnaires. The ' good ' psychologist seems to possess a distinctive pattern of interests and personality traits. On the basis of these results it is suggested that a battery of aptitude tests for psychology students might be devised which would be of considerable practical value.

Dr. W. Stephenson.—The psychological respectability of physical activity.

There is to-day a widespread interest in physical education and training—the whole nation has been appealed to and enjoined to become ' keep-fit conscious.' Most people would admit the importance of maintaining a certain minimum, at least, of physical fitness ; but the general public is perhaps insufficiently educated about the effects of bodily fitness upon mental condition, and psychologists have as yet given little attention to these effects. The present paper offers a brief review of the present state of our knowledge on this matter of the psychological effects of

bodily fitness. The corrective methods of F. Matthias Alexander are considered as an example, and some experiments on posture are described. The suggestion is made that physical activity would be more seriously regarded if more attention were given to it by experimental psychologists, who should provide the general public, and physical training experts, with a general theory upon which to base their thoughts and work on physical education.

Mr. W. H. N. Hotopf.—Some relations between characteristic interests of schoolboys.

About 500 boys between the ages of 11 and 16, mostly from elementary schools, were questioned in interviews lasting from 15 to 20 minutes about their interests and hobbies. The relations between these interests and the boys' test scores for intelligence and mechanical aptitude were examined. The interests of the boys were considered also from the point of view of temperamental qualities and general attitude and, where possible, the results were applied for the purpose of vocational guidance. The results were further examined for any light they might throw upon the question of changes of interest with age.

Mr. H. McRae.—Reliability of group intelligence tests.

Previous work with intelligence tests has indicated that the reliability of the test results is greatly impaired by the fact that individuals vary from week to week in their power to perform such tests. A special experiment was undertaken to investigate this individual variation.

About fifty pupils, tested individually about eight months previously, were given a series of six group tests of intelligence at weekly intervals. The resulting I.Q.s were worked out for each test. Due allowance was made for the fact that the median score and ' scatter ' varied from test to test, before the I.Q.s were finally compared.

Such a comparison constitutes the main part of this paper.

Apart from verifying that the tests used are not standardised on the same basis and that there is a definite practice effect over a series of tests given at weekly intervals, this investigation shows that individual variation (of more than twenty points in some cases) does exist, although it is suppressed and hidden in all work where the conclusions are based upon ' average results.'

Dr. E. A. Bennet.—Methodology in psychological medicine.

The classification of observations made in the course of clinical practice in psychological medicine is necessary if knowledge is to increase. Owing to the circumstance that our reflections proceed along different ways, we do not fix our attention upon the same objects. One will note the behaviour of a patient, another his physique, while a third notes only the working of the patient's mind. These three approaches may be loosely coupled together ; and one or other may receive special attention. When the third—the working of the mind—is included it involves the observation of mental activity both in consciousness and in the unconscious. It becomes necessary to employ a method suitable to this field. In such subjects as the science of history and the practice of psychotherapy events cannot be repeated. They belong to a certain time. Furthermore the personality of the psychotherapist is necessarily involved in the psychotherapeutic discipline. The value of the scientific method is so great that there is a desire in some quarters to universalise its application. An absence of subjective elements, observations tested

by experiment and capable of being repeated by another, are features of the scientific method. It is contended that this method is only partially applicable in psychotherapy. A method must therefore be used which will reveal the psyche and particularly the unconscious factors therein. As in physics so in psychology, a personal element enters. The method most appropriate at the present stage of our knowledge must include the recognition of individualistic as well as general elements. It is contended that such a method can be formulated ; and that by its use the material with which psychologists have to deal is made available and can be studied systematically. The use of individual material in a subjective manner is permissible if thereby we come to understand that the material is not only subjective—it is also objective ; and as such is subject to general considerations.

Dr. M. M. Lewis.—Recent developments in the psychology of language.

Dr. S. F. Nadel.—New field experiments on racial psychology.

The experiments described in this paper represent a combined psychological and anthropological effort. They were carried out in Nigeria in 1936, with subjects taken from two large tribes, the *Nupe* and the *Yoruba*. The aim of the experiments was to ascertain the extent to which differences in culture and race may affect psychological responses and dispositions. In each group a series of six different experiments was carried out, some of which—experiments on memory—have been published already (*British Journal of Psychology*, 28, 1937). The present experiments used verbal material, and were devoted to the examination of certain thought processes, namely, the formation of abstract concepts and of logical categories (e.g., opposites, cause-and-effect, etc.). The experiments reveal a marked divergence in the responses of the two groups, which can be correlated with cultural differences. As these thought experiments use material closely akin to that used in certain intelligence tests, the results are significant also with regard to the controversial question of inter-racial, viz. inter-cultural, intelligence testing. The divergence in the responses obtained from the two groups reveals the presence of specific qualitative factors in intelligence which do not lend themselves readily to quantitative comparison.

* * *

Dr. B. Semeonoff.—Common sense in music testing.

The main purpose of the investigation described was to devise tests of native musical ability, using material of a truly musical character. Many of the existing tests measure sensory discrimination, etc., which, though no doubt positively correlated with musical ability, present a test situation totally unlike the experience of making or listening to music.

Tests of a creative character were set aside for the time being, chiefly because the activity involved was felt to be strongly influenced by teaching—though the difficulty of separating innate from acquired musical ability became increasingly apparent. The tests used were partly based on the work of previous investigators, but with sufficient difference to be considered original. They comprised tests of musical knowledge, of interpretative ability and of musical taste. It is hoped later to add a test on the appreciation of musical form. The first of these consisted of a questionnaire, and the results were valuable chiefly as an indication of the ‘ musical status ’ of the individual. The other tests were based on the responses obtained on listening to gramophone records, the selections being, as far as possible, of relatively unfamiliar music. Different forms of the tests were applied to secondary school

children of about eleven to fifteen years of age, and to university students in the faculties of Arts and Music.

It is suggested that teachers and others interested may adapt the test material and method to their own requirements, since accurate standardisation seems neither possible nor altogether necessary.

Discussion on Training the mind.

Mr. Rex Knight

Training the mind, as distinct from stocking it with facts, is often neglected, because, as Dr. Mace has said (*The Psychology of Study*, p. vi) ' in our ordinary educational system, whatever is not a special " subject " is the business of no one in particular ; and training the mind is not a subject.' It used to be thought that mental training is secured merely by learning Latin, or Euclid, or some other such subject. But experiments, to which Mr. Hardie will refer, have shown that transfer of training is often lacking and always limited.

What is needed is express instruction and training in, *inter alia,* (i) the essentials of accurate and serviceable observation ; (ii) the best ways of improving the memory ; (iii) the technique of silent reading ; and (iv) the psychology of clear, logical thinking. These being trained should also be shown the other side of the picture—the errors of observation and memory and reasoning to which the mind is especially prone.

All this should be done in a concrete, realistic way. For example, in dealing with the non-rational methods by which people mislead themselves or are misled by others, the training must be useful and practical, like that set forth in Dr. Thouless's *Straight and Crooked Thinking*, and must also take full account of the great influence of emotional factors, which Dr. Mace will discuss.

Mr. J. L. Hardie

The nomenclature is misleading. It suggests the recrudescence of a belief, once piously held, that the mind is not so much a receptacle for facts but an instrument for dealing with facts, and that the teacher's primary concern is with the faculties of the mind rather than the medium in which the mind works. The essential problem may be stated thus : To what extent and under what conditions does the effect of training in one subject transfer to other subjects ? The results of experimental investigation indicate that the conscious application of ideals, principles, attitudes and methods produces some degree of transfer, while uninstructed or unintelligent practice does so only to a negligible extent, or not at all. But the orectic factors have not yet been adequately taken into account. The criterion for the inclusion of a subject in the curriculum should therefore depend not upon its value as a mental discipline, but upon its social utility. Two factors that militate against transfer are the lack of correlation in the curriculum, and the baneful influence of examinations. The effect of intelligence on the degree and the amount of transfer is not yet clear, but the assumption that the possibility of transfer is greater in children than in adults seems *a priori* reasonable.

Dr. C. A. Mace.

The problems defined by Mr. Knight, Mr. Hardie, and Dr. Thouless are urgent educational problems, but they are not purely educational ; since some of the chief influences upon habits of thought reside within the wider social background by which educational principles and policies are themselves conditioned. It is not

enough to cultivate the capacity for straight, clear, and accurate thinking; it is essential *to foster and maintain the will to think to good effect.* The problem of transfer is not one of the transference of acquired skills but of the transference of motives and attitudes. The development of appropriate attitudes is hindered within the school by factors such as those to which Mr. Hardie refers (curricula and examinations), but even when present in the treatment of school subjects the transference of these attitudes to extra-scholastic fields is made difficult by the social conditions which limit the utility of even the best of 'academic' intellectual attitudes when applied to 'practical' affairs. The psychologist interested in the 'functions' which processes subserve will take notice of the fact that there are situations in which bad thinking succeeds where good thinking fails.

Dr. H. L. Philp.—An experimental approach to the psychology of frustration.

Reports were made on different aspects of frustration as made manifest in the solving of puzzles. Pneumographic and psychogalvanic records were taken, while intelligence tests were given for control purposes.

The research indicated the general phenomenology of frustration to be (*a*) a confused experience of conative effort together with (*b*) increased emotional experience composed of negative self-feeling, disappointment, disgust, anger, etc. Light was also thrown on the causes of frustration, some being due to the blocking of biological goals, while others were connected with aims more consciously determined.

Among the conclusions were the following: (*a*) Conative activity when blocked tends to be changed into intense emotional experience, (*b*) the feeling tone of frustration is relatively fixed, while (*c*) there is possibly a quantitative principle of emotionality, this last-named having an important bearing on practical life as, e.g., in examinations of all kinds, or in one's power to work smoothly and effectively. Freedom from this type of emotionality has been expressed as a high degree of frustration tolerance. Incidental conclusions revealed that there are no correlations of any significance between puzzle-solving ability on the one hand and intelligence or perseveration on the other.

Dr. S. Rosenzweig.—Need-Persistive and Ego-Defensive Reactions to Frustration.

Types of reaction to frustration are divisible into those which serve to fulfil the frustrated need in spite of the obstructions occasioning frustration and those which serve to protect the inviolacy of the ego should the latter be threatened by the frustration. The former type of reaction is regarded as occurring invariably after frustration, whereas the latter occurs only under special conditions of ego-threat. Most behaviour following upon frustration involves both types of reaction, but pure cases of each are found and the theoretical distinction aids analysis.

An experimental study of memory offers an experimental demonstration of the distinction. *Unfinished* tasks are better remembered than *finished* ones when all tasks are performed in an informal setting. This result is consistent with the findings of Zeigarnik and Lewin. By contrast, *unsuccessful* tasks are less well remembered than *successful* ones when all tasks are performed in a formal test atmosphere which evokes excitement and pride and thus potentially threatens the ego. While the former set of conditions elicits need-persistive reactions in recall, the latter elicits ego-defensive ones.

Dr. J. Hettinger.—The ultra-perceptive faculty.

It has been alleged that by concentrating on an object a 'sensitive' is able to cognise items concerning its owner, generally miles away. An extensive experimental investigation of this process, referred to in Psychical Research by the misnomer of 'psychometry,' was carried out at King's College, London. Various 'control' methods were used and the results were statistically significant.

There followed a series of 'time factor' experiments. Recent events, including the actual time of the experiment, were found to constitute a large proportion of the items accurately cognised. This seems to indicate that the psychological make-up of the owner of the object at the time of the test may possibly be the source of supply of the items perceived.

The inference just referred to led to a new method of investigation, according to which the sensitive 'psychometrises' the object while its owner, miles away, peruses an illustrated paper. Time records kept at both ends show numerous instances of complete correspondence between the pictures and the items perceived; also distortions, the reason for which is easily discernible; and various other examples of thought-provoking relationships. These are illustrated by means of exhibits and lantern slides.

THE ATMOSPHERES OF THE PLANETS

By Dr. H. SPENCER JONES, F.R.S.

Being the Fourteenth Annual Norman Lockyer Lecture, delivered on December 6, 1938, in the Hall of the Goldsmiths' Company, London.

During the last few decades the main interests of astronomical research have shifted rapidly from the solar system outwards. The application of the spectroscope to the study of the stars and nebulæ, the use of photography, facilitating the study of faint objects, shortening the time of observation at the telescope, and providing permanent records, and the construction of larger and larger telescopes have made it possible for the astronomer to study objects at greater and greater distances. Whole new fields of research have been opened up, and the exploration of these has proved so attractive and has been so productive of results that the planets of the solar system have received much less attention than was formerly given to them. Nevertheless, the planets have not been entirely neglected in recent research. The great light-gathering power of large modern telescopes has enabled spectrographs of very high dispersion to be used for the more detailed study of the spectra of the planets, and the great advances in the manufacture of plates sensitive to the infra-red region of the spectrum have made possible the investigation of a region of the spectrum whose importance arises from the fact that the selective absorptions by planetary atmospheres lie mainly in this region. It is my purpose this afternoon to summarise some of the conclusions about the physical conditions on the planets derived from the investigations of recent years.

From theoretical considerations it is possible to decide whether or not any

planet may be expected to possess an atmosphere. The natural tendency of an atmosphere is to diffuse away into space. The molecules of the atmosphere are flying about in all directions at high speeds, continually colliding with one another and rebounding. In the upper layers of the atmosphere, the preponderant tendency is for them to be pushed outwards. They are prevented from escaping only by the gravitational pull of the planet.

In order to overcome this pull and to fly away into space, any particle, whether large or small, must acquire a velocity greater than a certain minimum value, determined by the mass and radius of the planet. If the radial component of the outward velocity is greater than this minimum value, the particle will escape from the planet, provided its motion is not impeded by collision with another particle.

In a simple gas, at a uniform temperature, the velocities of the molecules are distributed according to a law, discovered by Maxwell, which he first announced at the meeting of the British Association in 1859. The mean velocity of the molecules increases with the temperature, being proportional to $\sqrt{T}$; the number of fast-moving molecules with velocities much in excess of the mean velocity falls off very rapidly with increase of velocity. In a mixture of gases, the average energy of each type of molecule is the same ; the lighter the molecules the faster they move in the mean.

There are definite proportions of molecules with speeds of 10, 20 or 100 times the mean speed, so that there must be a progressive loss of fast moving molecules from the upper layers of the atmosphere of any planet. The rate at which this loss takes place depends upon the relative magnitudes of the velocity of escape and of the mean velocity of the molecules. The rates of escape were calculated by Jeans. He found that if the velocity of escape is four times the mean molecular velocity, the atmosphere would be practically completely lost in fifty thousand years ; if the velocity of escape is four and a half times the mean molecular velocity, the atmosphere would be lost in thirty million years ; whilst if the velocity of escape is five times the mean molecular velocity, twenty-five thousand million years would be required for the loss to be almost complete. The age of the planets is believed to be of the order of three or four thousand million years, so that if the velocity of escape is as great as five times the mean molecular velocity of hydrogen the atmosphere will be practically immune from loss.

The mean molecular velocity of hydrogen at 0° C. is 1·84 km./sec. At the observed maximum temperature of the Moon, 120° C., it is 2·21 km./sec. The escape velocity from the Moon is only 2·4 km./sec., so that an atmosphere of hydrogen would be lost from the Moon almost instantly. Similarly for Mercury ; the temperature of the sunlit face is found by measurement to be about 400° C. and at this temperature the mean molecular velocity of hydrogen is 2·9 km./sec., whilst the escape velocity from Mercury is 3·6 km./sec. ; a hydrogen atmosphere would again be lost almost instantly. It appears that the Moon, if it had never been hotter than at present, would have lost water vapour, nitrogen, and oxygen completely, but would have retained carbon dioxide and heavier gases ; Mercury, under the same supposition, would have lost almost all its water vapour and nitrogen and most of its oxygen, but would have retained heavier gases to a large extent. The rates of loss are likely to be underestimated because, as we shall see later, it is probable that when these

bodies were young and had temperatures much higher than they now have, the loss of atmosphere during the period of rapid cooling must have been considerable. It is certain that the Moon has no atmosphere now and this is fully in accordance with expectations. The evidence of an atmosphere on Mercury is not fully conclusive, but faint and transient shadings on the planet have been interpreted by Antoniadi as indications of an atmosphere. The observations are naturally difficult, but the conclusion of Antoniadi that Mercury may possess a very tenuous atmosphere is not in conflict with the theoretical evidence. It is certain, however, that most of the original atmosphere must have been lost.

Coming to the Earth, the escape velocity is 11·2 km./sec., which is almost exactly six times the mean molecular velocity of hydrogen at 0° C. Hence the atmosphere of the Earth should be immune from loss of hydrogen and all other gases.

At the present time the amounts of hydrogen and of helium in the Earth's atmosphere are very small. The spectrum of the aurora does not contain the lines of helium, an indication that the high regions of the atmosphere cannot contain very much helium. The total helium content of the atmosphere has been estimated to be about five parts in a million. The supply is being gradually replenished by the weathering of the igneous rocks of the earth's crust, which contain uranium and thorium and also, consequently, helium. Yet the atmosphere does not now contain more than a fraction of the amount of helium that it has gained in geological times in the process of the formation of sedimentary rocks as a result of the weathering of the igneous rocks. We may therefore say that there is direct observational evidence that helium is being lost from the atmosphere at the present time. It is believed that there may be a state of equilibrium between the rate of supply and the rate of loss.

Even if the Earth had remained hot, in the early stages of its existence, for a sufficient time for the hydrogen and helium then present in its atmosphere to escape entirely, it still remains to explain how helium continues to be lost when, according to the theoretical results, which are based on the accepted principles of the kinetic theory of gases, it should be immune from loss. There is one process by which the escape of helium can be brought about. It is well known that the night sky is faintly luminous. In addition to the light from the stars there is a faint luminiscence from the upper atmosphere, whose brightness seems to vary with the sun-spot cycle, being greater at sun-spot maximum than at sun-spot minimum. Lord Rayleigh has termed this the non-polar aurora. In the spectrum of the night sky the characteristic green auroral line, as well as the two red lines, are always present. These lines are emitted by oxygen atoms that are in what the physicists term a metastable state. An atom, when excited or loaded up with energy, usually unloads its energy, with the emission of radiation, within a short interval of time of the order of one hundred-millionth of a second. But a metastable state is characterised by the peculiarity that the atoms in that state have a very slight tendency to unload their energy. They may remain for an average time of a second or longer in that state before emitting their energy in the form of radiation. There is a high probability that before this occurs the atom will have collided with another atom. When a collision of a metastable oxygen atom with another atom occurs, the energy of the oxygen atom will be unloaded and converted into kinetic energy. The

two atoms will rebound with a greatly increased speed. By such a collision an atom of helium could acquire a speed of more than 12 km./sec., which is greater than the velocity of escape from the Earth. Hydrogen atoms would acquire a still higher speed, but heavier atoms, such as those of nitrogen or oxygen, would not by this process acquire sufficient speed to escape. They would receive an equal amount of energy but, being heavier, they would not move so fast. The loss of hydrogen and helium from the atmosphere of the Earth is thus made possible by the fact that free oxygen is present in the atmosphere.

It appears probable that the primitive Earth must have remained hot sufficiently long for most of its initial atmosphere to have been lost. It was pointed out by Russell and Menzel that in the stars and the nebulæ neon is as abundant as argon, whereas in the Earth's atmosphere argon is five hundred times more abundant than neon. Nitrogen is far less abundant on the Earth than in the stars ; it is ten thousand times more abundant in the Sun than on the Earth. These large differences in relative terrestrial and solar abundance demand explanation, because in general the relative abundance of elements on the Earth is in close agreement with their relative abundance in the Sun and other stars. These facts can be accounted for on the supposition that the rate of loss of atmosphere was very rapid when the Earth was hot. When the cooling had proceeded sufficiently far for the escape of the atmosphere to cease, neon had been depleted to a much greater extent than the heavier argon. If this supposition is correct, much of the original oxygen, nitrogen, and water-vapour and all the original helium and free hydrogen must have been lost. As the molten Earth cooled, great quantities of water-vapour, carbon dioxide and other gases must have been evolved from the solidifying magma ; these, with the residual gases from the initial atmosphere, formed the new atmosphere which, as the Earth was then relatively cool, could not escape.

It has been recognised for more than a century that the presence of free oxygen in the atmosphere of the Earth, which we are apt to take for granted without a thought, needs explanation. Oxygen is an element that is chemically active and processes are in continual operation that are depleting the store of oxygen in the atmosphere. One of the principal sources of depletion arises from the weathering of the igneous rocks to form sedimentary deposits—sand, clay and mud. The iron contained in the igneous rocks is not completely oxidised. The greyish hue of these rocks results from the iron being present mainly in the form of ferrous oxide. During the process of weathering, much of the ferrous oxide is oxidised into ferric oxide, which gives the red or brown tints to the weathered deposits. The amount of oxygen that is withdrawn from the atmosphere by this process is very considerable and it has been estimated that during geological times the amount of oxygen thus depleted from the atmosphere is about twice the quantity now present. It is clear that some process must be in operation which replenishes the oxygen in the atmosphere. The vegetation over the Earth's surface provides the means for this replenishment. The green plant absorbs carbon dioxide from the air and uses energy from sunlight to decompose it, the energy-transformer being the green colouring matter, called chlorophyll, contained in the plant cells. The carbon is used to build up the complex organic substances found in living plants, the oxygen being returned to the atmosphere as a by-product.

The supply of carbon dioxide is in turn renewed by the decay of vegetable matter and other organic materials. During the decay of such matter, oxygen is absorbed and carbon dioxide is liberated. This carbon dioxide is again available for building up new plant cells. Whenever organic matter is buried, as in coal measures and oil deposits, so that it cannot become oxidised and decay, there is a net gain of oxygen to the atmosphere. It seems probable that the present abundance of oxygen in the atmosphere has been provided in this way and that if the coal, oil and other organic deposits could be unburied and completely burned, the whole of the oxygen in the atmosphere would be used up.

The atmosphere of Venus is in marked contrast to that of the Earth. Venus is the planet which, of all the planets, most closely resembles the Earth in size, in mass, and in mean density. It is a little smaller than the Earth, a little less massive and has a slightly lower mean density. The velocity of escape from Venus is 10·2 km./sec., a little smaller than the corresponding velocity from the Earth. This velocity is about five times the mean molecular velocity of hydrogen, and it may therefore be expected that Venus will have an atmosphere, comparable with that of the Earth in extent and density. The presence of an extensive atmosphere is confirmed by observation. Her disk shows faint ill-defined transient markings, which are evidently cloud phenomena. No surface details are shown, even on photographs with infra-red sensitive plates. Photographs in ultra-violet light record cloudy markings which rapidly change their form and are of short duration.

The permanent cloud layer over Venus makes the determination of the period of rotation difficult; the cloud formations are not sufficiently long-lived to give any more definite information than that the rotation is not rapid. The spectroscopic determination of the period is difficult, but the evidence is in favour of a period of not less than 20 or 30 days. On the other hand, it is likely that the period is considerably shorter than 225 days, the period of revolution of Venus round the Sun, because it has been found by measurement that considerable heat is radiated from the dark side of the planet. Although the measurements show that the bright side sends us more heat than the dark side, the difference can be to a large extent explained by the reflection of sunlight from the cloud layer over the bright side. The small difference in temperature between the bright and dark sides is to be expected on a planet that is densely cloud-covered, the clouds acting as a blanket at night, provided that the length of the day is not too great. If the planet turned always the same face to the Sun, the difference in temperature between the bright and dark faces would be greater than is found by observation. Hence a rotation-period of several weeks seems probable.

The method used for the determination of the temperatures of the planets may be briefly described. The radiation received from the planet, or from a portion of its surface, is measured with a sensitive thermo-couple or bolometer. This radiation consists of two portions: reflected sunlight and long wave-length infra-red radiation from the planet. By placing a small transparent vessel containing water in the path of the rays the true planetary radiation of long wave-length is absorbed and the amount of the radiation that is merely reflected sunlight can be determined. Knowing, in this way, the amount of the true planetary radiation, the temperature of the planet may be estimated

approximately; this temperature refers to the radiating surface, and if the planet has much atmosphere the actual surface temperature may be considerably higher.

The measured mean temperatures of the planets are in close general agreement with the temperatures calculated on the assumption that for each planet there is a balance between the radiation received from the Sun and the radiation re-emitted into space. The temperature differences from one part of the surface to another depend very much, however, upon the extent and nature of the atmosphere. A dense atmosphere greatly reduces the variations of temperature across the surface and the range of temperature between day and night. The Moon provides an extreme example of rapid variations. At the lunar eclipse of January 14, 1927, Pettit and Nicholson found that the temperature of the surface dropped from $+ 70°$ C. to $- 80°$ C. in a little more than an hour, as the result of the radiation from the Sun being cut off by the interposition of the Earth. During $2\frac{1}{2}$ hours of totality, the temperature dropped a further 40° C. But after totality had ended, the temperature rose to almost its initial value in about an hour. Venus, on the other hand, despite its long day, shows only a moderate range of temperature.

To determine the composition of the atmosphere of Venus, or of any other planet, recourse must be had to the spectroscope. Absorption in the atmosphere of the Earth is a complicating and troublesome factor. Ozone, though present in the Earth's atmosphere in very small amount, with an equivalent thickness of but a few millimetres, completely cuts off the whole spectrum below λ 2900, so that the extreme ultra-violet region is completely inaccessible to observation. Oxygen reveals itself by some strong absorptions in the near infra-red and red regions, including the A and B bands of Fraunhofer and some weaker absorptions in the visible spectrum. Water-vapour has some extremely strong absorptions in the infra-red. The terrestrial origin of these various absorptions can be established in two ways. Firstly, by observing the spectrum of the Sun at different altitudes, the terrestrial absorptions become stronger the lower the altitude, because the air-path is correspondingly increased. Secondly, if the spectra of light from the east and west limbs of the Sun are compared, the absorptions of solar origin show a slight relative displacement caused by the solar rotation, whilst the absorptions of terrestrial origin are undisplaced.

The absorptions of terrestrial origin in the spectrum of the Sun having been identified, the absorptions produced in the atmosphere of a planet can be investigated by photographing the spectra of the planet and the Moon on the same night and at the same altitude. An absorption present in the spectrum of the planet and not in that of the Moon, or much stronger in the spectrum of the planet than in that of the Moon, must originate in the atmosphere of the planet. Another, and more delicate, method of investigation is to photograph the spectrum of the planet at a time when it is approaching or receding from us most rapidly. The motion will displace the absorptions due to the planet's atmosphere with respect to those due to our own atmosphere, and in this way the planetary absorptions may be revealed.

Complete information about the constitution of any planetary atmosphere is not obtainable, however, because many possible constituents of the atmosphere show no absorptions in the region accessible to study. Amongst such undetectable constituents are hydrogen, nitrogen, helium, neon and argon.

The investigation of the atmosphere of Venus has given no certain evidence of the presence of oxygen. Observations with the 100-inch telescope, in conjunction with the high-dispersion coudé spectrograph, have led to the conclusion that the amount of oxygen must be less than one-thousandth part of that above an equal area of the Earth. It must be remembered, however, that the observations refer only to the portion of the atmosphere above the permanent layer of cloud and this layer may be at a considerable height above the surface of Venus. More surprising, perhaps, than the failure to detect oxygen is the failure to detect the presence of water-vapour, even though the tests for water-vapour are less sensitive than those for oxygen. It would seem that the clouds on Venus must be clouds of water droplets, similar to the clouds in the Earth's atmosphere ; the explanation if the apparent absence of water-vapour may be that the atmosphere above the clouds is extremely dry.

The most interesting fact about the atmosphere of Venus is the great abundance of carbon dioxide. In 1932 Adams and Dunham discovered three well-defined bands in the infra-red region of the spectrum of Venus which are not found in the spectrum of the Sun, even when setting. They were evidently produced by absorption in the atmosphere of Venus. These bands had not at that time been observed in any terrestrial spectrum. Theoretical investigations indicated that they might be due to carbon dioxide ; this was confirmed when Dunham succeeded in obtaining a faint absorption, corresponding with the strongest of the bands, by passing light through 40 metres of carbon dioxide at a pressure of 10 atmospheres. Later, Adel and Slipher reproduced the three bands by passing light through 45 metres of carbon dioxide at a pressure of 47 atmospheres ; the absorptions so produced were less intense than the corresponding absorptions in the spectrum of Venus. Adel and Slipher concluded that the amount of carbon dioxide above the surface of Venus is equivalent to a layer two miles in thickness at standard atmospheric pressure and temperature. For comparison, it may be mentioned that the whole atmosphere of the Earth is equivalent to a thickness of five miles at standard pressure and temperature and that the amount of carbon dioxide present in the path of sunlight, when the Sun is setting, is equivalent to a thickness of only about thirty feet. Further confirmation is thus obtained of an abundant atmosphere on Venus.

The carbon dioxide will have a powerful blanketing effect, the escape of the long wave-length radiations being greatly impeded by the absorption by the carbon dioxide. It is not improbable that the temperature at the surface of Venus may be as high as, or higher than, that of boiling water. The high temperature, the lack of oxygen and the abundance of carbon dioxide can be interpreted as indications that there cannot be any great amount of vegetation on Venus and suggest that the planet is not the abode of life.

Mars occupies a position between Mercury on the one hand and Venus and the Earth on the other, as regards size, mass and velocity of escape. The velocity of escape is 5·0 km./sec., about one-half of the velocity of escape from Venus. It may be expected that Mars will have a much thinner atmosphere than Venus or the Earth. The presence of an atmosphere on Mars can be proved by photographing the planet in light of different colours. Photographs in the infra-red show permanent markings, which are evidently surface features, whereas photographs in the ultra-violet show none of these. By photographing

through filters which pass a narrow spectral region, it is found that the surface details become more and more distinct as the wave-length of the light increases. The atmosphere is extensive enough to scatter ultra-violet light to such an extent that the light cannot penetrate to the surface and out again.

The images obtained with ultra-violet light are larger than those obtained with infra-red light and the difference in size indicates that the atmosphere extends to a height of fully fifty miles above the surface.

The polar caps provide additional evidence of an atmosphere on Mars. As the summer advances over one hemisphere the polar cap gradually shrinks and disappears whilst the opposite cap, with the advance of winter, forms and grows. These changes are to be explained by the melting or deposition of ice, snow or hoar-frost, for the temperature is not low enough for the caps to consist of solid carbon dioxide. From the rate at which the caps decrease as summer advances it can be calculated that they are not more than a few inches thick, so that the whole quantity of water contained in them would be sufficient to make a lake of only moderate size. The caps are more prominent in ultra-violet than in infra-red photographs and are therefore partially atmospheric ; in winter, there is a permanent cloud layer above the pole.

Photographs by Wright, at the Lick Observatory, in light of different colours have given further confirmation of an atmosphere in the occurrence of clouds. The clouds are of two different types. One type of cloud is most prominent in the ultra-violet photographs. Such clouds must occur fairly high up in the atmosphere and must be sufficiently thin to allow the infra-red light to pass through ; these clouds have a tendency to begin to form at about Martian noon and to grow during the afternoon. It is probable that they are produced by the condensation of water-vapour, with the fall of temperature that begins at noon. The second type of cloud is seen on the infra-red, but not on the ultra-violet photographs. Such clouds appear yellowish to the eye. They must be at a fairly low level in the atmosphere and the yellowish hue is no doubt caused by atmospheric absorption.

All attempts to detect oxygen in the atmosphere of Mars have been unsuccessful. It can be concluded that the amount of oxygen is not more than one-thousandth part of the amount in the Earth's atmosphere. The red colour of Mars, which is unique among the heavenly bodies, provides indirect evidence of oxygen, suggesting rocks that have been completely oxidised. We may contrast the colour of Mars with the grey or brownish rocks of the Moon, which have not been oxidised. It appears probable that Mars may be a planet where the weathering of the rocks, followed by their oxidation, has resulted in the almost compete depletion of oxygen from the atmosphere.

The amount of water-vapour in the atmosphere of Mars is so small that it can be detected only under the most favourable conditions. At the Lowell Observatory, which is at an altitude of 7,250 feet, Slipher, in 1908, by comparing the spectra of Mars and the Moon when at the same altitude under conditions of exceptional atmospheric dryness in the winter, found that the water-vapour absorptions were slightly stronger in the spectrum of Mars than in that of the Moon.

Carbon dioxide has not been detected in the Martian atmosphere, which is not surprising since carbon dioxide must be present in large quantity before the absorptions in the region of the infra-red available for investigation can be

detected. There is some evidence of the existence of vegetation on Mars. Seasonal changes in form and coloration of the dark areas, light green changing to a darker green, and then to yellow and brown, seem to be reasonably well established. The interpretation of these changes as due to the seasonal growth of vegetation is plausible. The presence of some carbon dioxide in the atmosphere may therefore be inferred. Mars appears to be a world in the state that the Earth will ultimately reach when the oxygen in the atmosphere will have been almost entirely exhausted by the progressive weathering and oxidation of the rocks.

The major planets, Jupiter, Saturn, Uranus and Neptune, may be considered together. They are large massive planets, of low mean density, whose visible disks are considerably oblate. Their masses range from 317 times the mass of the Earth, in the case of Jupiter, to 15 times the mass of the Earth, in the case of Uranus. The mean densities of Jupiter, Uranus and Neptune are not greatly different from that of the Sun, which is 1·4 times the density of water ; Saturn has the lowest mean density of any of the planets, only seven-tenths that of water. The velocities of escape from all the major planets are so high, from 21 km./sec. to 60 km./sec., that extensive atmospheres are to be expected containing an abundance of the light constituents, hydrogen and helium, which have been lost from the atmospheres of the medium-sized planets.

The telescopic appearance of Jupiter and Saturn confirms the existence of dense atmospheres. Markings in the form of belts parallel to the equator may be seen ; these are of complex structure and their details are continually changing. Photographs in the infra-red show many differences from those in the ultra-violet, due to the greater penetration of the long-wave radiations into the atmosphere, but again the recorded features are continually changing, so that the infra-red light does not penetrate to the surface. Uranus and Neptune are too distant for detailed study of their surfaces, though faint belts parallel to the equator may be seen on Uranus.

Some theoretical results of interest have been obtained from the oblateness of these planets and the changes in the orbits of their satellites produced by the equatorial bulges of the parent planet. From investigations of this nature, Jeffreys concluded that these planets consist of a core of rock, generally similar to the inner planets in its constitution and of about the same mean density, surrounded by ice-coatings of great depth, above which are very extensive atmospheres. If these conclusions are accepted, some inferences may be derived about the thickness of the ice-coating and the depth of the atmosphere.

According to the calculations by Wildt, the rocky core of Jupiter has a radius of about 22,000 miles, so that it occupies only one-eighth of the whole volume corresponding to the visible disk ; the ice-coating is 16,000 miles in thickness and the depth of the atmosphere is about 6,000 miles. The rocky core of Saturn is about 14,000 miles in radius ; it is covered with a layer of ice some 6,000 miles thick, over which is an atmosphere extending to a height of 16,000 miles. The total weight of the atmosphere of Saturn is about equal to that of the rocky core. Saturn has the most extensive atmosphere of any of the planets, which explains why it has the lowest mean density and the most flattened disk of any planet.

The pressures of these extensive atmospheres are very great ; at the bottom of Jupiter's atmosphere, for instance, the pressure is fully a million times the

pressure at the bottom of the Earth's atmosphere. At a relatively small depth in the atmosphere, the pressure is great enough to compress the gas to a density nearly equal to that of the corresponding liquid. It is stated by Wildt that at the bottom of the atmospheres the pressure is great enough to solidify even the permanent gases.

The densities of the atmospheres are low ; according to Wildt's calculations they are 0·78 for Jupiter and 0·41 for Saturn. This enables most of the possible constituents to be excluded, for all known gases, in the liquid or solid state, have densities exceeding 0·3, with the exceptions of hydrogen and helium. Frozen oxygen, for instance, has a density of 1·45 ; nitrogen 1·02 ; ammonia, 0·82. In addition to helium and hydrogen, the only gases whose densities in the liquid or solid state are less than the density of the greater portion of the atmosphere of Jupiter are the hydrocarbons, methane, and ethane. There seems to be no escape from the conclusion that the atmospheres of the major planets must contain large quantities of free hydrogen and helium. This conclusion is in accordance with expectation. The planets are believed to have been formed in some way or other from the Sun, which is known to contain a large amount of hydrogen, to the extent of about one-third part by weight. Helium, oxygen, carbon and nitrogen are abundant in its outer layers. Massive planets, like the four major planets, would retain their light constituents ; hydrogen and helium are therefore to be expected to be present in large amount in their atmospheres.

The spectra of the major planets are of great interest. In the early days of spectroscopy Huggins discovered visually a strong absorption band in the orange and several weaker bands in the green in the spectrum of Jupiter. These bands appear more strongly in the spectrum of Saturn, but are not found in the spectrum of the rings—a conclusive proof that they originate in the atmosphere of Saturn. Uranus and Neptune show for the most part the same bands with still greater intensity, together with some additional ones. The great increase in the selective absorption from the yellow into the red and infra-red from Jupiter to Neptune accounts for the green colour of Uranus and Neptune ; most of the red and yellow regions of their spectra are lost by absorption. The investigations of Slipher during recent years have extended the spectra far into the infra-red to beyond λ 10,500 and have revealed several intense bands in that region.

The origin of these bands remained unknown until a few years ago. They had never been observed in the laboratory. Then Wildt succeeded in proving from theoretical investigations that certain of the bands agreed in position with bands of ammonia and that others agreed in position with bands of methane or marsh-gas. These theoretical conclusions were confirmed by Dunham, who, with the 100-inch telescope using much higher dispersion than had been available to Slipher, was able to obtain a more complete resolution of the bands into their component lines and found a complete coincidence. Dunham estimated that the quantity of ammonia gas producing the absorptions in the spectrum of Jupiter is equivalent to a layer 30 feet thick under standard conditions. The amount is less in Saturn. The ammonia absorptions are not detected in the spectra of Uranus and Neptune.

Methane is present in much larger amount. Adel and Slipher, in 1935, found that a 45-metre path of methane, at a pressure of 40 atmospheres, gave

bands intermediate in intensity between those of Jupiter and Saturn. The much greater strength of the methane absorptions in Uranus and Neptune is probably accounted for by the lower temperatures of these planets. The ammonia must be frozen out of their atmospheres, making it possible to see through them to a greater depth. Adel and Slipher estimated that 25 miles of methane at atmospheric pressure would be required to give absorptions as strong as those of Neptune.

The higher gaseous hydrocarbons, ethane, ethylene and acetylene, have been looked for in vain in the spectra of the outer planets. All the absorption bands appear to be accounted for by ammonia and methane. It is a grand slam.

The presence of ammonia and methane in the atmospheres of the large planets is not surprising. It is to be expected as a consequence of the large amount of hydrogen in the atmospheres. The picture, as painted by Russell, of the successive developments is as follows. When the major planets were hot, the hydrogen and helium were mixed with water-vapour, nitrogen and carbon dioxide. When the temperature fell below about 300° C., the carbon dioxide reacted with some of the hydrogen to produce methane and water-vapour, the partially reduced oxides of iron on the rocky surface exposed to hot hydrogen acting as a catalytic agent. With further cooling, at about the temperature at which the moisture began to condense, the free nitrogen would react with hydrogen to produce ammonia. There would then be an atmosphere of hydrogen, helium and other inert gases, mixed with methane, ammonia and water-vapour, but with little or no carbon dioxide or free nitrogen. Below this there would be a deep ocean, strongly alkaline from the ammonia in solution. As the temperature fell still further, the ocean would freeze. It may be mentioned that an ocean consisting of one part of ammonia to two parts of water would freeze at — 100° C.; all the four major planets are colder than this. The only constituents in the atmospheres that are capable of detection are ammonia and methane.

It used to be thought that the rapid changes shown by the markings on Jupiter were indications that the planet was hot. It was believed that it still retained a great amount of its original heat. The theoretical considerations of Jeffreys and the direct measurement of the temperature of Jupiter—which give a value of about — 135° C.—have shown that Jupiter must be intensely cold. The presence of ammonia and methane in its atmosphere provides further confirmation, if any lingering doubt remains, for, if Jupiter were hot, these gases would be dissociated. The ultra-violet radiation from the Sun gradually breaks up the molecules both of ammonia and of methane even at low temperatures. In the absence of oxygen, the break-up is followed by a natural recombination. From the quantity of ammonia observed to be present in the atmosphere of Jupiter, Dunham has concluded that the temperature cannot be lower than about — 120° C., if there is a large excess of hydrogen in the atmosphere. This is in close agreement with the directly observed value.

The ammonia in the atmospheres of Jupiter and Saturn must be nearly on the point of condensation and the clouds over these planets may consist of droplets of liquid ammonia or even small crystals of frozen ammonia.

The mean temperatures of Uranus and Neptune due to solar radiation

alone are about — 200° C. and — 220° C. respectively. At the temperature of Neptune the methane must be nearly ready to condense.

The nature of the planetary atmospheres, about which so little was known until recently, seems now to have been solved in its broad outlines. There are many details still not understood, such as the nature of the disturbances that continually occur in the atmosphere of Jupiter, and the cause of the colorations ; and it still remains a puzzle whether there is water or water-vapour on Venus. As a brief summary we find that we can divide the planets and their satellites into three groups : the small ones, entirely devoid of atmospheres ; the middle-sized ones, with atmospheres of moderate extent, devoid of hydrogen or hydrogen compounds but containing oxygen or compounds of oxygen ; and the large ones, with very extensive atmospheres devoid of oxygen or compounds of oxygen but containing hydrogen and compounds of hydrogen.

Printed in England at THE BALLANTYNE PRESS
SPOTTISWOODE, BALLANTYNE & CO. LTD.
Colchester, London & Eton

THE ADVANCEMENT OF SCIENCE

VOL. I. No. 4 JULY, 1940

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Dundee Meeting, August 30–September 1

When the Dundee Meeting was brought to a close after three days, it was decided that all communications of which the delivery was unavoidably cancelled should be taken as read. Abstracts (or titles) of communications are therefore printed in these pages whether the communications were delivered or not, and references to dates and hours, as furnished in the Journal issued at the Meeting, are excluded.

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THE ADVANCEMENT OF SCIENCE

NOTES

THE President and General Officers conveyed to Sir Buckston Browne, F.R.C.S., who presented Charles Darwin's home at Downe to the Association, their congratulations on the attainment of his ninetieth birthday, which fell on April 13 last. In his acknowledgment Sir Buckston Browne quoted : *Non cuivis homini contingit adire Corinthum.*

* * *

The Alexander Pedler Lecture was given by Prof. Allan Ferguson at Cardiff on March 14 last, in collaboration with the Cardiff Naturalists' Society. The subject was ' Splashes, and what they teach.'

* * *

George Radford Mather, who founded and endowed the Radford Mather Lecture in the Association in 1937, died on March 22 last, in his ninety-ninth year. He was born on October 17, 1841, at Irchester in Northamptonshire, and attended schools at Higham Ferrers and Northampton. At the first of them he acquired an early interest in physical science, which remained with him, through reading a life of Newton. After being apprenticed as an engineer and working for Allchin's firm in Northampton and J. & G. Rennie's in London, he established his own business in 1865 as a mechanical engineer and iron and brass founder in Wellingborough, retiring in 1909.

* * *

The Radford Mather Lecture is given, in accordance with the terms of the foundation, every three years. The first of the series was delivered by the Rt. Hon. J. Ramsay Macdonald, P.C., M.P., F.R.S., in London, on October 22, 1937, immediately before he left home for the voyage in the course of which

he died. The second lecture was given on May 20 last in Newcastle-upon-Tyne (where this year's annual meeting of the Association should have been held) by Prof. Sir Arthur Eddington, O.M., F.R.S., on 'The Story of the Nebulæ.' The lecture was arranged in collaboration with the Literary and Philosophical Society of Newcastle-upon-Tyne.

The Norman Lockyer Lecture, 1940, was appointed to be given by Prof. W. L. Bragg, F.R.S., on 'The Physics of Metals,' on June 24 at the University College, Hull, with the kind co-operation of the College authorities.

It was reluctantly decided, at the end of May, to cancel the Conference which had been appointed to take place at Reading on July 25–27. Arrangements were well advanced, and it is possible only to offer an expression of gratitude to all those who had helped to make them so.

At the moment when this note is written, it is not possible to forecast whether the next issue of THE ADVANCEMENT OF SCIENCE, due for publication on October 25, will appear at that date. Considerations of finance and the paper supply will have to be taken into account.

EDUCATION FOR INDUSTRY

ADDRESS TO SECTION L—EDUCATIONAL SCIENCE

By A. P. M. FLEMING, C.B.E., D.Eng., M.Sc.(Tech.)
PRESIDENT OF THE SECTION.

In presenting this address on Education for Industry, I would venture to call your attention to the part that the manufacturing industries play in our economic life. At a time when national security is a primary consideration, the significance of these industries is easily recognised. In more normal times, however, it may not be appreciated that on the state of industry directly or indirectly depends the material well-being of the entire population.

Many amenities which have profoundly affected our social and economic life, such as the widespread availability of electric power, rapid communication, accelerated transport facilities, etc., have been made possible only because the manufacturing industries have been able to turn new scientific knowledge to practical account.

The appropriate education and training of the personnel for such fundamentally important service is consequently a matter of national concern. To appreciate the requirements on which such education and training is to be based it is necessary to understand what industry really means.

The purpose of industry is to convert some natural resource into a form suitable for use by the community, as, for example, metallic ores which are transformed into innumerable appliances, the down of the cotton plant that eventually becomes clothing, the chemical energy of coal, or the kinetic energy of falling water, that is converted into electrical power. This transformation process, which we call industry, may, and usually does, include many stages, each one of which may constitute a separate industry, the finished product of one factory being the raw material of the next in the chain of operations between the original natural resource and the final manufactured product.

The fundamental need in this chain of processes is that each shall be accomplished with the minimum possible waste of human effort, materials and time, and it is evident that the problems involved in achieving this efficiency must be fully appreciated before the educational considerations affecting them can be planned and applied. To avoid any misconception of my meaning of this term efficiency, I wish to point out that the enlightened industrialist recognises that true efficiency depends upon every consideration being given to the well-being of the personnel in his organisation.

The transformation of natural resources involves the handling of a vast variety of different materials, each of which demands as a rule special knowledge and technique. For example, the manufacture of a modern electrical generator requires a variety of grades of steel each having some special physical

properties ; non-ferrous metals such as copper and a wide variety of alloys ; a miscellany of organic materials such as cotton, silk and linen fabrics, rubber and synthetic moulded products, varnishes, etc. ; and inorganic materials such as mica and asbestos.

Every new scientific discovery may have an important bearing on technical development, for it may suggest some new orientation of a process and thereby have far-reaching effects on the treatment and use of the materials involved in the manufacturing methods under consideration. Moreover, finality of form is never reached, due to the urge of engineers and research workers to effect improvements.

Apart from continual changes of a technical character, many developments have taken place in the organisation of industry, which present new educational needs. Industrial units have changed from privately-owned to limited liability companies. These in turn have grown in size, or become associated with other organisations in the same industry, or formed part of a co-ordinated chain of manufacturing concerns associated with the same ultimate product ; or again single or groups of companies making the same product have formed combinations to rationalise the distribution of output and to co-operate in eliminating manufacturing and other costs where overlapping occurs. Such combinations may be national or international in character. All these changes in organisation impose the need for personnel capable of filling a wide range of positions for each of which special training is needed.

Industrial conditions are thus never static, and therefore the personnel of industry must be ever alert to apply new knowledge wherever it affects their particular field of operation, and be fully adaptable to the changes in the processes of manufacture and organisation which result.

Preoccupied as he is with the technical, economic and administrative problems associated with continuous, and often very rapid, development, the industrialist is apt to overlook the need for constant attention to the educational reactions of this development, and of his associated responsibilities. On the other hand, and to an equal extent, those concerned with technical education especially may suffer from an unbalanced view as to the value of such education relative to all the other problems which face the industrialist. The difficulty of co-ordinating these two points of view is often responsible for an excessive 'time-lag' between the incidence of a new technique in industry and the preparation of a personnel capable of handling and utilising it effectively.

From the foregoing it will be appreciated that the evolution of industry involves a continual change in the character of the knowledge that must be applied by those engaged in it, if they are to achieve a continually increasing efficiency of production. How important this question of efficiency is to the whole community of an industrial nation may not always be appreciated. The material progress of civilisation demands an increasing supply of manufactured products of all kinds. Whether these products are manufactured at home or bought from abroad depends logically on where the production can be achieved most cheaply. If they are manufactured at home, employment is increased and money is available for circulation. This affects eventually all the community and not merely those workers directly engaged in industry. It is therefore of vital importance that the transformation we speak of as industry shall be conducted with the utmost efficiency, and to achieve this the

personnel engaged in it must be most effectively trained ; which in its broadest sense means most effectively educated.

Industrial personnel can be divided into two main groups : manual and non-manual workers. The first requirement of the manual worker is practical handicraft skill, and of the non-manual worker specialised knowledge applicable to the function he fulfils in the particular branch of industry concerned. To satisfy these requirements well-organised schemes of theoretical and practical training must be made available to all those fitted to take full advantage of them.

There are four main classes of entrants into industry, namely, those who enter at the school-leaving age from Elementary, Junior Technical, Central and Secondary Schools ; those from Secondary Schools who have attained School Certificate or Higher School Certificate standard ; those who have had University training ; and those adults who enter at any age and from any educational level. Of the first three classes, the University group contains the smallest proportion of misfits. At the lowest entry level economic need and local conditions of employment may, and usually do, determine the choice of vocation. In addition there is still considerable social prejudice in favour of the so-called ' black-coated ' occupations. The importance of vocational guidance in the early years cannot be too highly stressed, and although good work is being done in this direction much more is needed ; it should in fact be accepted as a responsibility by every competent teacher. Such acceptance implies, of course, familiarity with local conditions and opportunities. One useful adjunct might be the keeping, from school entry age onwards, of a record of the particular characteristics, aptitudes and preferences displayed by the pupil. Such a record would be of considerable value at the time when discrimination is made between Secondary, Junior Technical and Junior Commercial Schools. For those entering industry at the lowest stage there is, at present, little conscious preparation for industry from the educational point of view other than that in the Junior Technical Schools. The practical industrial bias given in these schools, for at least the two final years, is of definite advantage. Whether the selection of those proceeding to the Junior Technical School could be improved is open to question, but there is certainly no doubt of the advantage of this period of education to those who do follow it. A much greater proportion of Junior Technical School pupils who enter industry advance rapidly than is the case with their fellows not so educated. Indeed the tendency is for many of them to be recruited to the ranks of foremen, junior managers, draughtsmen and so on, with the result that the equally important field of artisanship is not very well fed numerically from this source. Records of one factory, compiled over a period of years, show that whereas 64 per cent. of the entrants from Elementary Schools became artisans, less than 10 per cent. of the entrants from Junior Technical Schools did so, in the same period.

The type of industrial training required for the manual worker who aspires to learn a trade or acquire a craft consists of a long period of practical experience with the tools, materials and processes of his chosen trade or craft and accompanying classroom education which may be secured by evening study in a

local part-time institution, by part-time day training, or in a works' school during working hours. The character of these studies varies considerably, but it is becoming increasingly desirable that they should lead to National Certificates as a course of this type provides sufficient basic technical knowledge. Moreover it provides a good basis for further study for the youth who is worthy of promotion.

For those youths who do not aspire to technical employment and whose natural bent is of a more practical character, the Workshop Courses provide an admirable adjunct to their practical experience.

Those who enter industry at the School Certificate or Higher School Certificate level have usually had the advantage of a preliminary science preparation which facilitates their acquisition of industrial process experience. Moreover their higher general educational level makes it possible for them to attain staff positions where their more maturely developed powers of judgment and their social attributes are of advantage.

Those who enter after University training have already acquired a considerable amount of knowledge of the technological and fundamental principles required in the particular branch of industry they select. A high degree of specialisation at this stage is extremely undesirable. It is of far greater value to be well versed in the fundamental principles of the selected and associated subjects. Indeed the latest tendency in industry is for any specialised training that may be required to be provided by the concern itself a year or two after entry. For example, in the Company with which I am associated there are several specialist training schemes in operation. The recruits for these schemes are, in the main, drawn from those University graduates who have acquired general experience in the factory for a period of one or two years. Such arrangements may, of course, be usefully supplemented by advanced courses of lectures where these are available at the local University or Technical College. One or two examples of such courses may be of interest. Design and development activities in engineering demand a continual influx of men who have received a considerable amount of technical and practical experience and are then prepared for specialist and advanced work. This preparation may take the form of special guidance in study and design work under a leading design engineer, together with lecture courses in the scientific developments allied to the particular subjects selected. Such courses apply in connection with the development of prime movers, generators, power transmission plant and power-absorbing devices, illumination and communication.

Much attention is now being devoted to the problem of finding suitable personnel trained to undertake the increasingly difficult problems of management. This is a matter of vital importance in ensuring continuity of progress in manufacturing concerns. It is essential that the selected men should be given preliminary and widely-applied responsibility before making use of such aids as the ancillary instruction now available in many technical institutions. A wise management recognises that giving promising young men a wide range of experience will bring out their latent capacity for administrative responsibility.

Recruitment for research work in industry is another case where the selection of personnel inherently suited for such work must be the basic factor. Methods of training research workers are beginning to evolve, but so far no

recognised plan is established. In my own laboratories general apprenticeship in the factory is followed by experience in several of the laboratories under the guidance of experienced research workers, supplemented by lectures on the work in their own and associated fields by senior members of the department. In some cases such workers are sent back to a University or other research laboratory for further experience.

There is a natural tendency to concentrate attention on those engaged in some form of handicraft skill or technical operations for which particular education and training are required. It must not be overlooked, however, that there are vast numbers of young men and women engaged in clerical and other branches of employment in industry. For the most part, however, their education and training can be adequately satisfied by the existing facilities.

The normal trend of industry and its corresponding educational requirements can to some extent be forecast, though contingencies arising from an abnormal international political situation may disturb this.

New scientific knowledge with its technical application is likely to continue to be a determining factor in industrial development. Continual improvement in efficiency of production tends to reduce the amount of labour required and to that extent accentuates the unemployment problem. On the other hand, out of scientific discoveries new products, processes and materials arise, and these, through the formation of new industries, contribute towards redressing the balance of employment. The film and the radio industries may be cited as examples of large-scale employment brought about by the technical application of scientific discovery. Such developments, however, emphasise the need for mobility and adaptability on the part of the personnel employed, because new industrial activities demand modifications to established handicraft technique as well as to the planning and organisation of production.

It is apparent that the mechanisation of processes, more particularly where repetitive work is involved, will become more extensive, and this should ultimately result in the securing of the necessary volume of production in shorter working periods—especially if employment could be more evenly distributed. Some of the time then available for additional leisure might be well employed in education of a cultural and social character and in physical training. By suitable planning it should be possible to reduce and eventually to eliminate the system of part-time evening study. The deficiencies of this system of technical education for those engaged in industry are well understood, but whether technical study is conducted in part-time day or part-time evening periods, the practice of compressing a large amount of highly specialised knowledge into intensive courses should be avoided. While appreciating the present usefulness of courses such as those leading to the Higher National Certificate, particularly to those young people who have no other means of acquiring the basis on which to proceed to technical employment, such courses should, in a planned educational system, be considered as expedients only. They provide neither the time for original, critical, or constructive thought, nor the means of developing latent personal qualities by any form of social and corporate life, and above all it is important to encourage educational methods which develop ability to think independently rather than simply to

add to a store of knowledge. That so many young people succeed by the existing methods is a tribute to the individual rather than to the system.

Certain industrial activities, notably those associated with supplies such as water, gas and electricity, are easily recognisable as public services. As time goes on there will be a growing realisation that every industry is in fact a national service, although it may be conducted, as at present, by private enterprise. Considered in this light the importance of employing every means of increasing the efficiency of industry becomes apparent. Among other considerations, it is obviously essential to utilise all the facilities available for the training in numbers and in quality of its personnel. The conventional system of education is subject to control by national and local educational authorities, but there is no control over the equally important practical side of education for the industrial worker. No national means exist whereby a standard can be set for this phase of education, nor in fact are the resources for training in industry fully utilised. The *laissez faire* methods whereby the quality and extent of practical education of industrial personnel depends on a relatively few progressive industrial concerns compare unfavourably with the planned and more efficient methods that are possible in authoritarian countries. Under present conditions this weakness can be remedied only by more complete voluntary co-operation within industry. Such co-operative effort would relieve the burden that now falls upon a few individual firms. An effective way of stimulating this might be the remission of income tax on the money expended on such training. Control could be instituted by restricting the remission to courses approved by a suitably constituted authority.

The establishment in industrial firms of separate 'nursery' workshops in which the fundamentals of handicraft skill and machine operations are taught concurrently with the appropriate workshop instruction will become more widespread. A few schemes of this type are already in operation in private firms and in a number of Government establishments in this country, while the method has been extensively developed in Germany and to a lesser extent in other countries. Experience will show at what stage the trainee should be transferred from the 'nursery' workshop to the normal manufacturing conditions.

The result of introducing manual training at an early age such as exists in the educational system in Russia will be watched with great interest.

In contrast to this, with the raising of the school-leaving age, the tendency in this country will be for young people to enter industry for practical training at progressively increasing ages. This may involve a more intensive period of practical training, but the difficulties of this should be offset by the greater maturity of the trainees concerned, which the longer period of general education will ensure.

An educational problem that is already acute and will be even more so in the future is the supply of suitable teaching staff for the Universities and Technical Institutions. Formerly much of the scientific and technical development relating to industry came from the Universities. Due largely to the establishment of large-scale research by industrial concerns and to the great expansion of their technical staffs the initiative in progress has passed to industry, and many scientists who previously found their vocations in academic life are now attracted to scientific and technical employment in industry.

The result is that in those faculties in which the work has a technological bearing there is a great shortage of personnel available for teaching, so that the time is opportune for the Technical Institutions and Universities to consider a long-term policy as regards selecting and training those who will eventually become the academic leaders. The practical industrial side of this training is of paramount importance. In this connection co-operation should be arranged with industry to provide a suitable range of practical experience without the permanent absorption of the personnel so trained. Industry has already shown its willingness to co-operate with education in this respect by providing short 'refresher' courses for those in academic employment who have little opportunity of maintaining close contact with industrial developments. The technical knowledge and experience of eminent technologists in industry might well be utilised more completely than at present by co-opting such men to the professorial staffs of Universities and Technical Colleges, and thus augmenting, for special courses, the existing teaching facilities. New technical processes now arise so rapidly from scientific discoveries and become so promptly established in industry that the text-books used for teaching purposes can never be completely up to date. The introduction of Post-Advanced Courses in the Lancashire area appears to be the correct solution to this problem. These courses, which comprise short series of lectures on specific technical subjects, are given mostly by experts in industry and are conducted on a basis of exposition and discussion. They serve admirably the needs of the technologist in industry who is endeavouring to bring himself up to date in a new subject.

The greater availability of technical scholarships and fellowships might well serve as a means of attracting suitable personnel to industrial employment. The extension of fellowship facilities available for those who seek experience abroad is extremely valuable, particularly if these are awarded to men who have already had sufficient experience to know definitely in what particular directions they wish to supplement their existing knowledge. In the past many educational opportunities of this type have not been used to the best advantage due to the immaturity of those receiving the awards, who have not had sufficient experience to appreciate fully that educational and industrial methods can never be transferred wholly from one country to another because social and economic conditions differ. Some industrial organisations have established Research Fellowships, whereby University staffs can spend time in industrial research organisations, which provides experience of inestimable value to the fellowship holder on his return to academic life.

As yet there is no clearly defined and assured path by which a youth can proceed through the various stages of education into industrial employment. The national system of education provides the means whereby those of suitable ability can obtain education and training up to and including the University or Technical College level, but the practical training in industry and an assured start in a job is at present fortuitous. In this direction there is room for greater co-operation by industry to ensure the completion of the industrial training and a start in the chosen career. Such an arrangement would give direction and impetus to the various stages of preparation between school or college and industry, would cut down some of the time spent in obtaining what may be

unnecessarily detailed technical knowledge, and moreover would relieve both the youth and his parents of a good deal of anxiety.

Greater co-operation than at present exists between education and industry is essential in regard to the syllabuses of workshop and technical studies appropriate to the educational level at which entrance into industry is made. Equally also co-operation is needed to ensure the adequacy and up-to-date-ness of the laboratory and workshop equipment of the Technical Institutions and Universities.

Any attempt to improve our methods of education has an immediate and obvious advantage from the industrial point of view. All education should be liberal and even to meet the urgent needs of industry no technical specialisation should be permitted which excludes the possibility of time being devoted to broadening the mind in both the mental and the social sense. Men and women who have been trained to think for themselves, rather than merely to assimilate facts, are bound to develop valuable habits of constructive criticism and be the more ready to utilise and develop new ideas. Since science plays an ever-increasing part in the development and progress of new products of industry, a knowledge of scientific principles and of their economic significance is essential to the proper utilisation and appreciation of these products. Consequently it is highly desirable that elementary science should have a definite place in general education.

In this address I have purposely stressed the technical aspects of education for industry, since these to a considerable degree serve also as a basis for the industrial education of the personnel in those branches of industry not directly of a technical character. In so doing I am acutely conscious of the risk that, speaking as an industrialist, I may convey the impression that industry is concerned with the education of its personnel in a narrow sense only. This is far from being the case. I cannot too strongly emphasise the need for the education of those engaged in industry to be characterised by broad aims and to be linked up with the world outside.

SECTION L.—EDUCATIONAL SCIENCE

COMMUNICATIONS

Discussion on Education as a preparation for industry.

Mr. W. O. Lester Smith.

The importance of a sound general education and the significance of Hadow reorganisation. The entry to industry, choice of employment; our educational neglect of the adolescent and the consequent wastage of human material. The Fisher Act and the Day Continuation School. The Spens Report and the post-primary curriculum. The organisation of technical education; regional co-operation. The necessity for a constant revision of the subject-matter of technical education in order to meet the needs of a competitive and scientific age. Facilities for the training of technical teachers, for transmitting knowledge of new processes, and for circulating the achievements of research.

Dr. K. Fisher.

Mr. B. Mouat Jones.

Discussion, led by Dr. J. A. Bowie.

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Discussion on Education in industry.

Industrial concerns.

Mr. J. B. Longmuir.

Educationists, in giving nearly all children the kind of course which leads to a university, have neglected the many. The raising of the school-leaving age is a splendid opportunity to make amends.

Commencing with a summary of the educational requirements for those in industry, the extent to which these are being met are described.

It is claimed that the educational requirements of industry are just as necessary for the full enjoyment of the leisure hours as for the full enjoyment of the working hours of the future citizen.

Employers' obligations for the technical education of young workers, the limitations of works schools, evening continuation classes and the possibility of introducing day continuation classes are discussed.

Mr. G. L. Darbyshire.

Range of employment represented by London Midland and Scottish Railway.

Methods of recruitment and qualifications for engagement.

Training arrangements, with particular reference to commercial and operating and engineering departments.

Internal education—Classes for instruction in : Goods and passenger station office work ; Block signalling ; Locomotive working ; Permanent way maintenance ; Signal and telegraph maintenance ; Lectures on special problems.

External education : Arrangements with Educational Authorities ; Encouragement for staff in further education.

Films for instructional purposes ; Departmental publications as instruments of staff education.

First-aid classes and safety-first instruction.

School of Transport, Derby.

Part-time education outside the works.

F. T. Chapman.

Those in industry for whom technical education is needed can be considered in three groups :

(*a*) Craftsmen ; (*b*) Technologists ; (*c*) Managers and administrators.

In each case the training presents three aspects :

(*a*) Learning of techniques ; (*b*) Acquisition of skill ; (*c*) Study of technology.

The outstanding problems are concerned with (*a*) the apportionment of the training required between systematic instruction in schools on the one hand, and practical experience on the other, and (*b*) the best methods of co-operation between industry and educational institutions.

Principal J. Cameron Smail, O.B.E.

Technical education in Britain has been built up largely on part-time education mainly in evening classes. The results have undoubtedly justified the scheme, but the strain on individuals is considerable. Day classes have been suggested and urged for many years, and have been in operation in dockyard schools and various works schools and in particular industries such as printing, but no joint national scheme operates. The outstanding results of the dockyard scheme show the

possibilities for educated students. The personnel for control, organisation, administration and design has been largely recruited through part-time education. The psychological value of the 'sandwich' system is insufficiently appreciated and further investigation is desirable.

Colleges are confronted with difficulties in staffing and equipment, the varying degrees of sympathy and indifference of employers and the consequent variation in the attitude of students. Advances by industries are clearly indicated and the shortage of well-educated young people, owing to various causes, is likely to force the matter to a definite issue in the near future.

Post-Advanced work.

Prof. Willis Jackson.

It is now widely accepted by industrial concerns that the primary function of University courses in applied science is not to provide them with ready-made specialists, but rather to develop the ability to think deeply and critically in terms of those fundamental principles which underlie all the specialised branches of a particular applied science. With this growing recognition has come the recent development in local areas of post-graduate courses of instruction—termed Post-Advanced Courses, since they serve the needs also of those men who have proceeded through part-time evening courses to Higher National Certificates—of a specialised technological character appropriate to the industrial needs of these areas. The paper outlines the nature of some of these recently organised courses and discusses the educational principles involved.

Discussion, led by Mr. C. A. Oakley.

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Discussion on Aspects of industrial research.

Mr. T. M. Herbert.

This paper discusses the functions of an industrial research department, with special reference to its introduction into an established industry such as a railway. A description is given of the gradual development of the L.M.S. Research Department, and of certain problems inevitably encountered in the early stages of its growth. The ultimate effects of an active research department within an industrial undertaking are analysed.

Examples of the type of work undertaken are given in the paper, which is illustrated by a film of a semi-popular character.

Dr. W. G. Radley.

During the past twenty years there have been very great developments in the facilities extended to the public for inter-communication by telephone, telegraph and radio. The telecommunications systems which provide these facilities incorporate complex equipments and devices which are the results of very recent research in physics. The Post Office system is maintained by an engineering staff of 45,000. The theoretical and technical training of this staff is therefore an important problem and the paper indicates the means that have been taken for its solution. The paper also describes the means that are taken for the training of supervisory staff who may be responsible for research and future development.

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Discussion on Recent educational research in Scotland.

Prof. W. McClelland.

The paper deals with certain special investigations conducted under the Scottish Council for Research in Education, including studies of the prognostic value of

University entrance examinations and of methods of selection for secondary education.

Mr. W. A. F. Hepburn.

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Discussion on The Spens Report.

Miss L. Grier.

The Report considers the relations between the education of children leaving school at sixteen and (*a*) those leaving at some later age ; (*b*) those leaving at some earlier age.

The last question simplified by the proposal to raise the school-leaving age to sixteen and complicated by the reaffirmation and the recommendation that all education after eleven should be Secondary. Variety to be maintained by schools with different objectives and under different management. Numerous suggestions made for lessening the domination of Universities, of examinations and of subjects.

Mr. J. B. Frizell.

(1) Differences between educational systems of England and Scotland making for difficulties in assessing the report from the viewpoint of Scottish educational administration.

(2) The leading conceptions of the report : (*a*) reform of secondary education ; and (*b*) developments in technical education.

(3) Barriers to achievement of the Committee's purpose and recommendations for their removal.

(4) Report in general corroborative of educational thought and practice in Scotland : its bearing on Scottish educational administration.

(5) Ways in which the report may influence educational administration in that country, particularly (*a*) Curricula ; (*b*) School Certificates ; (*c*) Technical Education ; and (*d*) School Organisation.

Mr. A. E. Henshall.

Limitations imposed by Committee's terms of reference. Wider survey occasioned far-reaching recommendations by the Committee in regard to organisation and administration of the system of secondary education.

Interests to be considered when the curriculum of secondary schools is discussed. Conditions to be fulfilled by the content of the curriculum ; suggested outline of a curriculum to satisfy these conditions. Safeguards necessary, if facilities for University education are to be provided and narrow specialisation is to be avoided. The Technical High School, its function and place in the secondary system. The content of general education.

Discussion, led by Mr. D. E. Collier.

THE INFORMATIVE CONTENT OF EDUCATION

SECOND REPORT of the COMMITTEE appointed to consider and report on the gaps in the informative content of education, with special reference to the curricula of schools (Sir RICHARD GREGORY, F.R.S., Chairman; Mr. G. DUNKERLEY, Vice-Chairman; Mr. A. E. HENSHALL, Secretary; Prof. C. W. ATTLEE, Miss L. HIGSON, Mr. A. GRAY JONES, Mr. D. SHILLAN, Dr. F. SPENCER, Mr. H. G. WELLS).

INTRODUCTION.

AT the conclusion of the Report presented last year a summary was presented of the results of a questionnaire, by means of which an attempt had been made to discover what measure of correspondence existed between the actual curricula of schools and the *Informative Content of Education* as outlined by Mr. H. G. Wells in his Presidential Address, Section L (Education) at the Nottingham Meeting of the British Association for the Advancement of Science. Therein it was stated that there appeared to be a consensus of opinion 'that the informative content of education outlined by Mr. Wells is both too wide in scope to be covered during the present school life of the great majority of children of this country, and too advanced in its demands upon the capacity of the pupils for whom the various sections of the subjects were suggested.' Attention was, however, directed to the differences of opinion revealed by the answers to the questionnaire, especially in regard to the sections which could and should be included in the curriculum ; and it was noted that what some correspondents thought could not be taken with pupils of a given age-group, or could not be included within the scope of a reasonable curriculum, was actually being taken by schools for pupils of the given ages.

Reference was also made to another reason which might account for the fact that the replies to the Committee's questionnaire were not wholly satisfactory. It was pointed out that the phraseology used by Mr. Wells, necessarily adapted to the audience to whom it was delivered, was not likely to be appropriate for use in schemes of work for schools. This fact was obvious when the terms used in the suggested scheme for infants were examined. To speak of 'Elementary human cultures and their development in time,' 'States of Matter,' 'Biology,' 'Zoology,' 'Botany,' and 'Physiology' for children of seven years of age is to arouse suspicion if not antagonism; and to expect children of this age to have knowledge of any of these was thought unreasonable. Yet the opinion was expressed to the Committee that much of the actual information which Mr. Wells suggested should be taught, if not all of it, might be acquired by children by the time they reach the age of seven years, either through the stories told to them and the books they read or through the medium of Nature talks, observation records, gardening and such normal activities, all of which are part of the ordinary work of nearly every infants' school in the country.

INFANTS' SCHOOLS.

In the pursuit of their enquiry, therefore, the Committee decided to take steps to test the soundness of this opinion. With this object in view they endeavoured to discover how far the information referred to in the part of Mr. Wells' scheme for children of seven years of age was gained by such pupils. Accordingly, questions which covered the whole of the sections of the work were prepared and the assistance of head teachers of infants' schools, willing to conduct the enquiry, obtained. In addition, the co-operation was sought of head teachers of junior schools, where the local conditions of transfer of pupils resulted in children of the age of seven being in

their charge. Obviously it would have been impossible with the limited machinery at the disposal of the Committee to conduct a comprehensive investigation throughout the country. Nor was this necessary for the purpose of obtaining evidence that the scope of the work Mr. Wells proposed was within the comprehension of children of the given age and that the information was, in fact, actually acquired by some of the children. Typical schools were therefore chosen, and as these were situated as widely apart as Sunderland and Rhondda, Sheffield and London, the results may be accepted as illustrative of what will be found in the State schools.

Results of a Test.

The following table gives the questions together with the percentage of accurate replies for each of five different schools. Those given for A, B, C and D are the results in classes where the pupils are actually seven and not over eight years of age. Those for E are for an ' A ' class (that is, the brightest children) in an infants' school ; these pupils were only six years of age.

	School				
	A	B	C	D	E
Number of pupils	55	36	25	116	36
I. *Human Cultures and their Development in Time.*	%	%	%	%	%
(1) What name is given to the place where you live with your father and mother ?	100	67	100	75	60
(2) In other lands there are other kinds of houses. What kinds have you heard of ?	100	59	70	55	50
What people live in snow houses ?	100	59	50	90	78
What people live in caves ?	80	28	10	6	—
What people live in tents ?	100	84	60	60	65
What people live in huts ?	50	28	50	8	35
(3) What men of whom you have heard					
(*a*) lived in a cave ?	25	84	30	7	14
(*b*) lived in a tent ?	30	56	15	41	20
(*c*) lived in a hut ?	2	50	5	20	—
(4) How did the men who lived in caves obtain their food ?	90	61	50	50	50
What did they use to catch animals ?	60	64	35	9	60
What did they use to catch fish ?	30	20	15	64	45
What else did these men obtain from animals ?	50	70	40	95	63
What people use furs for clothing ?	60	78	45	40	70
Who use sheep skins for clothing ?	30	84	10	25	—
What other use is made of skins ?	90	47	40	26	—
Who were the enemies of men who lived in caves ?	100	61	35	45	66
What did they do to be safe from wild animals ?	100	33	20	30	48
(5) Later, men found an easier way to obtain food. What did they do to be sure of animal food ?	—	36	—	8	—
What did they do to be sure of food from plants ?	10	47	5	8	3
(6) When they had tame animals what did they have to do to obtain food for them ?	5	44	10	10	16
(7) When they moved from place to place how did they provide shelter for themselves ?	25	70	10	22	30
(8) How did they get coverings for their tents ?	50	64	40	56	70
(9) When people began to grow food plants what was it necessary for them to do ?	2	14	5	27	3
(10) If they had to stay in a place for a longer time what difference would that make to their shelters (or tents) ?	10	28	10	34	3
(11) How would they make them stronger ?	25	28	15	16	3

	School				
Number of pupils	A 55	B 36	C 25	D 116	E 36
	%	%	%	%	%
(12) When twigs were used to fill in spaces between wooden uprights what would have to be done to keep out the rain?	10	36	10	35	66
Where can such mud huts be seen to-day?	2	22	10	7	70
(13) When people lived in tents and huts how did they get the things which they could neither obtain from animals nor from plants?	25	25	—	2	—
(14) With whom might they exchange them?	50	8	15	12	8
(15) Later they exchanged goods with people who lived in other districts.					
How did they take the goods?	80	28	20	20	—
What name is given to animals which carry goods?	—	42	—	75	—
What 'Beast of Burden' have you seen in this country?	80	64	50	20	60
Of what other beasts of burden have you heard?	90	56	50	—	70
Where is the camel used?	90	53	45	72	68
Where is the dog used to draw carriages?	75	70	30	60	70
If the people had to cross water what would they need?	100	92	65	61	80
(16) When some people had many cattle and others had none what would those who had none try to do?	25	47	35	35	—
What might this lead to?	40	50	35	60	11
If they fought what would the victors be likely to do?	2	14	40	60	6
II. *States of Matter.*					
(1) If water is in a jug and you wish to put some of it into a glass what do you do?	100	81	90	75	65
(2) What else can you pour from a jug into a cup or a glass?	100	92	100	86	72
(3) What name can be given to water, milk, beer and tea?	2	8	30	40	6
(4) If a stone were in a jug and you tried to pour it into the glass what would happen?	30	64	100	76	70
(5) Why can't you pour a stone into a cup?	10	75	45	20	50
(6) Name anything else besides a stone that cannot change its shape and that cannot run from one vessel to another.	60	97	80	27	—
(7) What name is given to stones, iron, wood, etc.?	—	6	35	6	14
(8) When water is placed in a kettle and heated what happens?	100	47	80	64	28
(9) If allowed to continue to boil what becomes of the water?	60	64	60	28	68
(10) If during winter water is left in a bowl outside the house what sometimes happens to it?	100	78	55	55	53
(11) What is the difference between water and ice?	20	72	25	28	65
(12) What three forms can water be made to take?	50	59	45	10	10
III. *Geography.*					
(1) What can be seen in the sky during the day?	100	78	95	65	60
(2) Where does the sun rise?	100	56	40	85	14
(3) When is it highest in the sky?	100	64	40	42	78
(4) What does the sun do before night?	75	56	60	55	8
(5) When you face the sun what can be seen behind you?	100	78	50	60	66
(6) At what time in the day does your shadow point					
to the west?		11	15	30	11
to the north?	14	42	25	60	60
to the east?		6	20	46	—
(7) What sometimes hides the sun?	25	86	65	95	90

	School				
Number of pupils	A 55	B 36	C 25	D 116	E 36
	%	%	%	%	%
(8) What different kinds of clouds have you seen?	100	50	35	20	70
(9) What do dark, heavy clouds bring?	100	89	75	78	73
(10) What causes the clouds to move across the sky?	50	47	35	37	67
(11) What is wind?	100	6	20	7	16
(12) Which wind brings rain?	70	70	45	18	—
(13) Which wind brings snow?	100	75	50	47	22
(14) Which wind is a warm wind?	4	64	15	40	—
(15) Which is a stinging wind?	100	11	50	63	56
(16) What is the name of the nearest river or stream?	70	64	15	68	28
(17) Where does the river flow to?	2	47	53	20	33
(18) How do men cross seas?	80	92	100	80	33
(19) When do people go to the seaside?	80	97	75	82	78
(20) What other places do people go to for holidays?	50	53	85	82	60
(21) What is the nearest mountain or hill to your school?	—	86	10	22	11
Between hills or mountains there is often a stream.					
(22) What name is given to this land between hills?	20	78	35	26	60
(23) Why did men make railways through the valleys?	5	11	20	23	50
(24) What do all the seas and land make up?	20	50	15	17	35
(25) What is the earth sometimes called?	100	3	50	17	25
(26) What shape is the world?	10	78	55	70	—
IV. *Biology.*					
(1) What animals do we have in our homes?	100	95	100	100	70
(2) What kind of animals are the cat and dog?	75	50	50	60	72
(3) What other animals are like the cat?	70	47	35	24	—
(4) Where are tigers found?	60	81	45	30	35
(5) What other animals are like the dog?	60	33	25	20	53
(6) Where is the wolf found?	30	50	15	2	25
(7) What animal is most like a man?	90	28	25	27	—
(8) Where are apes found?	20	50	30	43	42
(9) What other animals are found in forests?	50	44	50	40	45
(10) Which of these are found in warm countries?	100	50	40	57	53
(11) Which of these are found in cold countries?	80	84	65	63	67
(12) What animal does man use to work for him?	80	84	90	70	78
(13) What other animal is like the horse?	8	20	75	65	80
(14) Where is the zebra found?	5	89	30	10	56
(15) What animals provide food for man?	60	75	100	75	28
(16) Where are sheep found?	30	75	95	40	67
(17) What do men get from goats?	75	53	30	68	60
(18) Where are wild goats found?	—	11	10	38	50
V. *Descriptive Zoology and Botany.*					
(1) What do wild animals eat?	5	42	45	10	—
(2) Which of them eat plants?	5	95	30	18	33
(3) What plants do men eat?	100	92	100	67	33
(4) Sometimes the roots are eaten. Which foods are roots?	60	67	55	38	50
(5) Which plants give fruits that can be eaten?	100	92	100	70	11
(6) What happens to apples and pears allowed to remain on the trees when they are ripe?	2	64	50	40	23
(7) What birds peck them?	2	44	45	24	3
(8) What other creatures sometimes eat apples and pears and plums?	10	42	15	18	60

	School.				
Number of pupils	A 55	B 36	C 25	D 116	E 36
	%	%	%	%	%
(9) Where do wasps live ?	2	11	5	10	45
(10) What creature besides the wasp has a sting ?	80	95	90	60	—
(11) Why do bees visit flowers ?	50	81	75	80	53
(12) How do bees help the plants ?	10	39	65	6	80
(13) Where are the seeds of apples found ?	60	86	100	30	—
(14) Where are the seeds of flowers found ?	10	33	80	60	60
(15) How are seeds scattered ?	10	89	50	40	67
(16) What animals help to scatter some seeds ?	5	20	20	34	47
VI. *Elementary Physiology.*					
(1) If you wish to grow a pea plant what do you do with the seed ?	10	95	80	75	67
(2) Why is it placed in the ground ?	5	70	50	20	70
(3) If it were placed in dry sand what would happen ?	50	42	40	56	60
(4) What must the seed have then ?	60	89	75	80	56
(5) Which part of the plant begins to grow first ?	5	53	55	60	60
(6) If the plant is kept in a dark cupboard what kind of growth does it make ?	2	14	60	20	50
(7) What must plants have to grow into strong, healthy plants ?	60	50	50	50	50
(8) What would happen if animals were kept without water ?	75	81	100	67	67
(9) What would happen if animals were kept without sunlight ?	2	78	80	20	6
(10) What would happen if animals were kept without air ?	75	92	100	50	53
(11) What can animals do that plants cannot do ?	80	42	45	63	15
(12) If animals are not allowed to move about, what difference does it make to them ?	60	22	35	20	16
(13) What must animals have besides water, light, air and food ?	5	20	30	24	14
(14) What creatures sleep in the daytime ?	60	47	30	24	14
(15) Why do these creatures sleep during the day ?	5	25	35	12	40
(16) What animals catch their food by night ?	70	33	50	30	44

Other head teachers submitted the results of the tests in another form, and gave the percentage of satisfactory replies for each of the sections.

The following table indicates the results as thus recorded :

Section.	Results.			
	School F.	School G.	School H.	School I.
	%	%	%	%
I. Human Cultures and their Development in Time	80	50	57	37
II. States of Matter	50	62	74	51
III. Geography	60	56	69	51
IV. Biology	70	50	54	53
V. Descriptive Zoology and Botany	50	59	58	55
VI. Elementary Physiology	50	54	64	53

One head mistress gave an analysis of the results which showed how many questions were answered accurately by each of the 43 pupils in the class. In the first section—*Human Cultures*—1 pupil answered the whole of the 40 correctly ; another 39 and another 38 ; 25 were able to answer 30 or more ; 12 others more than 20 ; and only 7 failed to answer 50 per cent. of the questions.

In the second section—*States of Matter*—4 had all correct, 5 all but one, and 10 all but two. Only 4 failed to score 50 per cent. The third section—*Geography*—had 25 questions. One had all correct, two had 24 correct, one had 23 and four 22. Eighteen answered 80 per cent. or more correctly, and only five had less than 50 per cent. right.

In *Biology*, of the 18 questions, 2 had all right, 8 had 17, 8 had 16, 6 had 15 and 6 had 14. In answering questions on this section only 2 failed to answer 50 per cent. In *Zoology*, of the 15 questions, 4 had all correct, 7 had 14, 2 had 13, 4 had 12 and only 5 failed to answer at least 50 per cent. The questions in *Physiology* gave rather more trouble to this class, 12 failing to score 50 per cent. Two, however, had all 16 correct, one had 15, and two had 14.

This teacher forwarded the written answers of a pupil to illustrate the method used in testing. The summary of results indicated that the information which Mr. Wells suggested might be gained by children of the age of seven was actually acquired by some of the pupils.

In commenting on the questions and answers, one head teacher made the following observations :—

Section I (*Human Cultures*).—The question on barter and exchange was not understood at first. The term ' Beasts of burden ' was not known, but their work and kinds were well and quickly given.

Section II (*States of Matter*).—The terms ' liquids,' ' solids,' and ' gases ' were not known, but good equivalents were offered, e.g. ' Pouring things,' ' Things you hold,' ' Steam.'

Section III (*Geography*).—The cardinal points were not generally known ; 12 per cent. knew them well and answered well. 100 per cent. was the result regarding questions on nearest hill, river, etc.

Section V (*Zoology and Botany*).—In this section, 50 per cent. standard was reached. A higher standard would have been reached had the children grasped some of the questions better ; e.g. ' How are seeds scattered ? ' to which the answer was given, ' You throw them so.' A similar point was made by two other head teachers in reference to several questions, though no such reference was made by any of the others. This fact, however, illustrates the difficulty inherent in framing questions for young children without a knowledge of their school and home life, and therefore of their normal vocabulary.

Another return showed the results for the whole of the questions. Counting each part of a question as one, the total number of marks obtainable was 128. The questions were answered on paper by all the thirty 7-year-old children in the class. The results obtained are shown on the following page.

The Head Teacher wrote : ' I have given you the complete results, including those of the " dull and backward " ones. The result was 76 per cent. ; counting 50 per cent. of the marks as a pass, there were 23 out of 30 who passed.'

No. of marks gained.	No. of children.	No. of marks gained.	No. of children.
93	1	68	1
89	1	67	2
84	1	66	2
80	2	65	3
79	1	64	1
78	2	62	1
75	1	50	2
74	1	44	1
73	1	43	1
72	1	40	1
71	1	34	1
69	1		

General Observations.

An examination of all the results recorded suggests that the scope of the work included in this section of *The Informative Content of Education* is within the comprehension of children of the given age-group. In one case the head teacher of a senior school who witnessed the giving of the test remarked that it might have been thought that some of the questions had been based upon an actual scheme of work used in the school.

All the questions were not equally well answered by the pupils in any school and, of course, there were marked differences between the schools. The questions on some sections occasioned more difficulty than those on others. For example, the means by which man ensured a supply of food by taming animals does not appear to have been so well known. There were, of course, difficulties in the use of terms, like 'liquids,' 'solids,' and 'gases,' where these had not been taught; but even these were known in many cases.

There would appear, therefore, to be no reason, if it be agreed that the information indicated by Mr. H. G. Wells in Grade A should be taught, why it cannot be taken with children of this age-group.

JUNIOR SCHOOLS.

The nature of the replies to last year's questionnaire from head teachers of infants' schools necessitated the use of questions such as those to which reference is made in the preceding pages. With regard to junior schools, however, the position was different. It will be recalled that the replies received from head teachers of these schools indicated that definite plans of work were formulated and, in some cases, that the scope of the work suggested by Mr. H. G. Wells in his address on *The Informative Content of Education* was actually covered.

In reference to these schools, therefore, the Committee endeavoured to obtain copies of syllabuses in actual use. These, it was thought, would illustrate the measure of agreement between what was, in fact, being taken in some schools and what was suggested by Mr. Wells.

Each subject was considered, and head teachers who had reported that what Mr. Wells suggested was taught in their schools were requested to supply copies of their syllabuses in that subject. A number of head teachers readily responded, and interesting syllabuses were received. From these the following are quoted. The fact should be borne in mind that they are schemes of work for children of the ages 7 to 11.

I. History.

(a) A London Junior Mixed School.

Main Purposes of the Scheme.

(1) To explain the place occupied by British History in the story of the world, and more particularly in the story of the people of Europe.

(2) To furnish pictures of human life connected with tales of human experience, and types of human conduct in the chief epochs and among the chief races of mankind ; and to foster feelings of human sympathy and admiration.

(3) To convey some idea of the long and difficult process by which human civilisation has come to be what it is, and the debt under which we lie to the great men of all nations.

(4) To give an outline of the story of the British people, with clear pictures of the representative incidents and representative men and women ; and to connect this outline with the state of the nation at the present day.

(5) To give some conception of the growth of London and to take advantage of visible monuments that connect the present with the past.
Visits will be paid to museums and buildings of educational value, or of local, national or historic interest.

(6) To suggest duties and opportunities which free citizenship implies, both in local and national affairs.

Outline of Scheme.

1st and 2nd years : People of Long Ago.

In simple form, the story of these peoples of long ago whose thoughts and works have greatly influenced the development of the British race, and are still influencing it to-day.

An attempt is made to cover, in bold sweeps, a stretch of the history of antiquity, on its social and picturesque side. The childhood of nations is the fittest material—rich with old fancy and adventure—and preserves the living spirit of the earlier ages. The spirit and temper are akin to those of young children ; the conditions of human life which they depict are simple, striking and easily imagined.

(The scriptures of the Old Testament cannot be studied intelligently without some rudimentary knowledge of the ancient Empires of Egypt, Assyria and Persia, for the history of the Hebrews is, to a great degree, an account of their relations with those Empires.)

Some summary notions about the Greeks and the Romans.

3rd year : A Set of Lessons on Famous Men and Famous Deeds.

Continuation of the above story to modern times in the form of biographies.

Deals mainly with personal character and prowess, discovery, invention, and with the way in which men have lived and worked. A study of general history, in rudimentary form, revealing the truth that Englishmen are under a debt hardly less great to the people of other nations than to their own. Any tendency to confine the attention solely to our own country is indefensible ; it cannot but tend to produce insularity of ideas, and to foster that false sense of patriotism which ignores or despises other countries.

4th and 5th years : Making the Homeland ; Building the Empire.

Story of the British race from earliest times to the present day.

An attempt at a brief and rudimentary introduction to the 'science of history' and to some concrete ideas of how a history book comes to be written, what material the historian uses, and what kind of evidence he has for his statements.

Systematic lessons on citizenship, local and national, and the high and responsible duties of every Englishman to-day. Understanding of the great changes in national life and the rights and duties of a citizen.

Visits to historical places, collections, etc., with lessons interwoven to stimulate interest.

Lantern slides.

Details of Scheme.

1st year. *Class* 5.

People of Long Ago.

The story of those peoples of long ago whose thoughts and works have greatly influenced the development of the British race, and are still influencing it to-day.

1. A Great Traveller of Long Ago.
2. The Meeting of Isaac and Rebecca.
3. Joseph and his Brothers.
4. David and Jonathan.
5. The Nile and the Pyramids.
6. The People of the Nile.
7. Two Great Cities, Babylon and Nineveh.
8. The First Great Sea Traders.
9. A Great King of Persia.
10. The Wonderful Land of Greece.

The Tale of Troy.

11. The Coming of Paris to the Palace of Menelaus.
12. The Fight of Hector and Achilles.
13. The Departure of the Greek Ships from Troy.
14. How the Romans made their Empire.

2nd Year. *Class* 4.

People of Long Ago.

1. A Great Traveller of Long Ago.
2. The People of the Nile.
3. Two Great Cities, Babylon and Nineveh.
4. The First Great Sea Traders.
5. A Great King of Persia.
6. The Wonderful Land of Greece.
7. Helen of Troy.
8. Solon and Crœsus.
9. Pheidippides the Runner.
10. Leonidas the Spartan.
11. How the Romans made their Empire.
12. Romulus and Remus.
13. The Childhood of Horatius.
14. Horatius and the Bridge.
15. Regulus.

3rd Year. *Class* 3.

1. A Famous Conqueror : Alexander the Great.
2. A Famous General : Hannibal.
3. A Famous Roman : Julius Cæsar. How he came to Britain.
4. Some Famous Wanderers : The Goths.
5. A Famous Prophet : Mohammed.
6. A Famous Ruler : Charlemagne.
7. Some Famous Warriors : The Crusaders.
8. A Famous Saint : St. Francis of Assisi.
9. A Famous Peasant Girl : St. Joan of Arc.
10. A Famous Explorer : Christopher Columbus.
11. A Famous Preacher : Martin Luther.
12. A Famous Monarch : Louis XIV of France.
13. A Famous American : George Washington.
14. Another Famous Conqueror : Napoleon.
15. Some Famous Inventors.
16. A Famous Patriot : Garibaldi.
17. A Famous Queen : Victoria.

4th Year. *Class 2.*

1. Old Stone Men ; New Stone Men.
2. The Men who used Bronze. The Men who used Iron.
3. The Britain of Long Ago.
4. How the English changed Britain into England.
5. Alfred the Great.
6. Edward the Confessor and William the Conqueror.
7. The Normans take possession of the English villages.
8. The Village Church and its Priests in Norman Days.
9. Life in a Monastery ; its food and money ; the Friars.
10. A Great King and a Great Archbishop.
11. Some Boys and Girls of Long Ago.
12. The people gain power from the Kings.
13. A Mediæval Town in the time of Edward III.
14. The Black Prince and his son Richard.
15. Two Great Leaders : Henry V and Joan of Arc.
16. The First English Printer.
17. Warwick the Kingmaker.
18. An English Town of Long Ago.
19. The Great Tudor Rulers.
20. Sir Thomas More.
21. Good Queen Bess.
22. Mary Queen of Scots.
23. Drake and the Men of Devon.
24. A peep at Shakespeare's London.
25. Dissolution of the Monasteries ; Changes in the Parish Church.

5th Year. *Class 1.*

1. Changing Times.
2. Scottish Kings and English Subjects.
3. Civil War in England.
4. Puritans and Cavaliers.
5. Oliver Cromwell.
6. The King comes back.
7. Whigs and Tories.
8. English life in the Seventeenth Century.
9. The Duke of Marlborough.
10. Sir Robert Walpole.
11. William Pitt and Empire Expansion.
12. London Life in the Days of Dr. Johnson.
13. George III and Empire Losses.
14. New Ways for Old.
15. Coal, Iron and the Steam Engine.
16. The Rise of the Cotton Manufacturers ; a Lancashire Cotton worker.
17. The Coming of the Factories.
18. The Coming of the Railways.
19. Nelson and Wellington.
20. Remarkable changes.
21. Sir Robert Peel and Free Trade.
22. Gladstone and Disraeli.
23. Empire Builders.
24. Our own times.
25. The British Commonwealth of Nations.

(*b*) A Cannock Junior Mixed School.

Points to Note.

Full scope should be given to the constructive and expressive powers of the children in making models, drawing pictures and picture charts, or acting scenes from the lives of which they have heard or read.

The children themselves should take an active part in the lesson, and not be merely passive listeners. They should be encouraged to ask questions and to re-tell the stories which they have heard.

The stories should be illustrated with large pictures showing a particular incident in the story, or with simple blackboard sketches in coloured chalks giving details of the dress, housing, ships, weapons, etc., of the period in which the story is set.

1st Year (7–8).

1. The Children of the Trees.
2. Ko, the Cave Boy.
3. Big Grom, Little Grom and their Boat. (New Stone Age.)
4. The Shining Axe. (Discovery of Metal and its Usage.)
5. Bel of the Blue Lakes. (Life in a Lake Village.)
6. Men who baked their books.
7. Nebka of the Nile. (Egypt 6,000 years ago.)
8. Joseph in his own Land.
9. Joseph in Egypt.
10. How Hanno sailed the Great Seas : a story of Tyre.
11. The Olympic Games.
12. Cyrus, King of the Persians.
13. A Boy of Ancient Greece (Xenophon.)
14. Pheidippides the Fast Runner.
15. How Esther saved her People.
16. Gwent the Briton (20 B.C.)
17. Pericles of Athens.
18. Alexander and his Horse.
19. Alexander's March to India.
20. Romulus and Remus.
21. Horatius.
22. Mucius the Left-handed.
23. Coriolanus.
24. Hannibal crosses the Alps.
25. Julius Cæsar.
26. How the Eagles came to Britain.
27. 'The Die is Cast.'
28. The Travelling Emperor, and his Great Wall in Britain.
29. Saint Paul.
30. The Story of the Flaming Cross.

2nd Year (8–9).

1. Nathan the Little Jew. (Holy Land, 10 B.C.)
2. Alaric the Goth.
3. Harald of the Creek.
4. Mohammed.
5. Charlemagne.
6. Hugh of the Greenwood. (Life about A.D. 1160.)
7. The Crusaders.
8. St. Francis of Assisi.
9. Martin the Tumbler. (Thirteenth Century.)
10. How Pete went to London. (Wat Tyler.)
11. Joan of Arc.
12. Little Lady Margaret. (A.D. 1588.)
13. Martin Luther.

16. Patience the Little Pilgrim.
17. Louis the XIVth of France.
18. Oak-apple Day.
19. Kit the Charcoal Burner. (Iron Industry, A.D. 1700.)
20. George Washington.
21. Gillet Sharp the Weaver's Son. (Woollen Industry, A.D. 1730.)
22. Napoleon.
23. Sally Sims, the Little Spinner. (Cotton Industry, A.D. 1730.)
24. Some Famous Inventors.
25. Paul Somers makes the Great Trek.
26. Mary Martin emigrates to New Zealand. (1850.)
27. Garibaldi.
28. Queen Victoria.
29. Nurse Cavell.

3rd Year (9–10).

1. The Britain of Long Ago.
2. How the English changed Britain into England.
3. Alfred the Great.
4. Edward the Confessor and William the Conqueror.
5. How Oakleigh Hall was built.
6. A Great King and a Great Archbishop.
7. Some Boys and Girls of very long ago.
8. How the Lord of Oakleigh returned from the Holy Land.
9. The People gain power from the Kings.
10. How the Lord of Oakleigh went to France : and how Oakleigh fared in the days of 'The Death.'
11. The Black Prince and his son Richard.
12. Two Great Leaders, Henry V and Joan of Arc.

13. Warwick the Kingmaker.
14. White Rose and Red.
15. An English Town of Long Ago.
16. Sir Thomas More.
17. How an Oakleigh sailed the Southern Seas.
18. Good Queen Bess.
19. Mary Queen of Scots.
20. Drake and the Men of Devon.
21. A Peep at Shakespeare's London.
22. For King or State.
23. When Bonaparte watched our shores.
24. Oakleigh Manor and the Great War.

4th Year (10–11).

1. Columbus discovers the New World.
2. Two Martyrs.
3. The Tragedy of a Queen.
4. Sailing round the World.
5. Kings and Queens in Tudor and Stuart Times.
6. The Pilgrim Fathers.
7. The King and the Commons.
8. The Pilgrim who went to Prison.
9. The Fire of London.
10. Great Lighthouses.
11. The Seven Disobedient Bishops.
12. The Man of Fashion and the Preacher.
13. Clive in India.
14. Wolfe in Canada.
15. A Great Inventor.
16. Nelson at Trafalgar.
17. The Surrender of Napoleon.
18. Swift Nick of the Highways.
19. The First Railway.
20. The Great Trek.
21. The Lady of the Lamp.
22. Australia's Brave Explorers.
23. A Great Missionary.
24. A Great President.
25. A Great Life-saver.
26. The Children's Friend.
27. The Story of the Atlantic Cable.
28. The First Flight Across the Atlantic.
29. ' In this Sign, Conquer.'

II. Geography.

(*a*) An Ealing Junior School.

1st Year.

(1) *Children of Other Lands.*

The Red Indian.
The Eskimo.
The Dutch.
The African Pigmies.
The Arabian.
The Japanese.
The Kirghi.
The Swiss.
The Norwegian.
The Greeks.

All these lessons should be freely illustrated by drawing, modelling, either by individuals or as class efforts.

(2) *Simple Map-making.*

1. My Walk to School.
2. My Walk to the Station or to the Main Road.
3. Maps to illustrate certain stories : e.g. Winnie the Pooh visits Christopher Robin.

(3) *Physical Geography.*

Simple explanation of physical phenomena as they occur, viz., snow, rain, hail, fog.

The Sun. Where it rises and sets. Sun shadows, when long, when short.

2nd Year.

(1) *Many Things from Many Lands.*

Market Day in a Market Town.	Dates and Deserts.
Going Shopping.	Tea, Rice and Silk.
A Fur Coat.	More about Tea.
The Daily Newspaper.	A Reel of Cotton.
Our Bread.	Rubber and its Story.
Canterbury Lamb.	The Harvest of the Sea.
Oranges and Lemons.	All Sea Roads lead to Britain.

(2) *Physical Geography.*

Simple explanations of all natural phenomena as they occur in the lessons above.

A River. Source, basin, tributary, mouth, etc.

The work of rivers, sea, ice, etc.

Deserts, oases.

(3) *Map-making.*

Simple maps and plans of local features and the surrounding neighbourhood, not to scale, but with a reasonable amount of proportion.

Cardinal points.

All lessons to be well illustrated by pictures, and where possible models made by the children.

Occasional short written tests to be given.

3rd Year.

(1) *Round the World.*

Modern Methods of Travel.	From India to China.
Westward Ho ! The Atlantic Ocean.	China.
Across Canada.	Across the United States.
Canada to Japan.	South America.
Across the Old World.	The Dark Continent.
Eastward Bound.	New Zealand via Panama.
The Nile and the Desert.	The Australian Commonwealth.
India.	The Polar Regions.

(2) *Physical Geography.*

Explanations of physical phenomena introduced into lessons above.

The Earth's Crust, Mountains, Hills, Valleys.

Land and Water.

The above with special references to local features.

Rainfall, effect on productions.

Map-tracing and simple plans.

Modelling and drawing should be used to illustrate lessons where possible, and later in the year an attempt should be made to draw plans to scale.

4th Year.

(1) *The British Isles.*

The Bread Lands.	Ireland.
The Orchard Lands.	Ireland to Wales.
The Pennine Moorlands.	Counties of the South-West.
Market Towns and County Towns of the North.	Lowlands of England and Scotland.
Ports and Fishing Towns.	London.
The Way to Scotland. The Highlands.	The Railways.

The above lessons to be accompanied wherever possible by brief notes, and sketch maps.

(2) *Local Geography.*

Talks on Local Industries.
Visits when possible to Local Factories.

(3) *Maps.*

Contour lines and sections.

(4) *Physical Geography.*

Temperature. The Thermometer. Isotherms.
Rainfall. The Barometer. Isobars.
Physical causes of World Regions.
Typical Productions and Peoples.
Connection between Climate and Occupations.
Day and Night.
The Seasons.

(*b*) A Cambridge Junior School.

General Considerations.

1. The work must be thought of in terms of activity and experience.
2. The work must be suited to the development and interests of the boys.
3. Two main sections :
   (i) Observational work, Home Geography, Mapping.
   (ii) Regional and World Geography.

Age-Group 7 to 8 years.

Section I.

Simple weather records as rain, snow, sunshine, wind, leading to elementary facts of climate.
Rain—where it comes from, where it goes ; value ; why does the river sometimes overflow its banks ? ; wearing of the roads.
The River and the Railway ; where they go, and what they carry.
Apparent daily movements of the sun—shadows.
Wind vane.
A map of my classroom—where I sit.
The way I go home.

Section II.

Folk Tales and stories of people in other lands—Eskimos, Negroes, Chinese, Desert folk, Forest folk, Grassland folk—to bring out the main facts of their environment—nature of country, climate, and how they live—food, shelter and clothing.

Age-Group 8 to 9 years.

Section I.

Weather records including wind charts—cold and warm winds, wet and dry winds.
Simple plans of classroom, school and playground, streets near the school.
Measurement by pacing to lead to idea of simple scales.
The cardinal points.
Rivers and running water—our sluggish river, contrasted with mountain streams.
Hill, mountain and valley.

Section II.

Types of relief—highland, lowland ; coasts.
Types of climate—hot, cold, wet, dry.
Types of life—hunting, fishing, pastoral, agricultural, manufacturing, trading.

Study of pictures, and reading of simple descriptive stories of the people and their environment.
Illustrative handwork.

Age-Group 9 to 10 years.

Section I.

Weather records introducing the thermometer and barometer—making simple graphical records.
Plan of the school district.
The use of colour layers to show configuration—introduced by pictures and air photographs side by side with map.
Scales of maps as development of scale drawing of simple plans.
The map of England—position of Cambridge and other known places on the map.

Section II.

British Isles—relief, climate, occupations, some important towns.
Geography of the more common products of the World—tea, sugar, rice, wheat, wool, cotton.

Age-Group 10 to 11 years.

Section I.

The map of Cambridgeshire—climate and soil, crops, industries.
The Fens and their drainage.
Study of maps of other countries—comparative areas leading to a simple idea of density of population.

Section II.

Simple studies of the principal geographical regions of the British Isles and how interrelated.
Simple World studies—mainly a welding of the facts learned in previous classes, a conception of the World as a whole, the position of the continents, oceans, more important countries, and a few cities.

III. Science.

(*a*) A Cannock Junior School.

Nature Study.

Points for consideration of class teachers.

(1) The main aim of the teaching should be to keep alive and quicken the spirit of wonder and inquiry and to give it appropriate scope for activity.

(2) A special task of the Junior School is to satisfy a growing desire to construct. This can be met by giving them practical work to do in connection with their first-hand observation of plant and animal life.

(3) The children's observations need to be directed by questions, and their experiences are incomplete if they do not express them in concrete form such as written notes or drawings. Modelling in suitable material is a useful aid to visualising form and structure, and the making of notebooks and portfolios for nature records gives scope for other handwork activities. The children should be encouraged to make simple insect cages, to fit up small aquaria and wormeries, and to grow their own seeds and bulbs at home.

(4) Make full use of the School Garden, as much of the subject-matter has been chosen on the assumption that the children will be watching the plants and insects which may be found there, and that individual interests in it have been established.

(5) The value of Nature Walks, each with a definite object in view, should not be overlooked.
(6) Nature Calendars: records of wind and weather, plants and animals, seasonal arrival and departure of common birds, etc., to be kept as in Geography Scheme.
(7) It is very important in Nature Lessons to see that every child has actual specimens to observe and examine. The provision of one or two to be shown to the class as a whole is almost useless.
(8) In the earlier stages the children should make straightforward observations and collect simple facts.

1st Year (7 *to* 8).

Autumn Term.

Preparations made by plants for the next year.
Study of Fruits:
1. To understand what is meant by a fruit. Snapdragon. Plum.
2. General knowledge of fruits in a hedge.
3. Some winged and succulent fruits and their dispersal.

Planting of seeds and bulbs (class garden plot).

Spring Term.

1. Continuation of above idea.
   Life history of a hyacinth and study of the bulb.
2. Life in water.
   Animal studies: (i) goldfish; (ii) frog.
3. Spring awakening:
   (*a*) The awakening of the hedge;
   (*b*) Horse chestnut and sycamore seedlings.

Summer Term.

Full life and flowering time.
1. Flowers' dependence upon insects. The pollination of flowers as the condition of seed formation.
   Hawthorn, Bluebell, Sycamore (the last wind-pollinated).
2. Insects' dependence upon plants.
   Life history of a common butterfly and a common moth.

2nd Year (8 *to* 9).

Autumn Term.

1. As last year, preparations made by plants for next year.
   Fruits:
   (*a*) In the hedge: Blackberry, Hips and Haws, Hazel Nuts, Wild Parsnip or Cow Parsley, Burdock.
   (*b*) In the garden: Hollyhock, Nasturtium, Apple.
   Bulbs: Daffodil.
2. Resident winter birds; how they obtain food.
   Soft-billed: Blackbird, Thrush, Starling, Robin.
   Hard-billed: Sparrow, Finches, Yellow-hammer.
3. Hibernation of animals. Study of snails, Chrysalids.

Spring Term.

Spring awakening.
1. Birds which come inland or southward; Water birds, Fieldfare.
2. Animals which winter in the soil: Earthworms.
3. Growth of Daffodil. Hazel catkins, Willow catkins. Broad Bean, Mustard and Cress, Sunflower seeds.

Summer Term.

1. Further flower study: Buttercup, Poppy, Wild Rose, White Dead Nettle, Sweet Pea, Dandelion, Groundsel, Thistle, Goatsbeard (chiefly for their fruits).
2. Climbing plants: Sweet Pea, Runner Bean, Wild Rose.
3. Continuous study of snails. Life history. Slugs.
4. Life in water: Pond snails, Pond insects, e.g. Water Beetle, Dragonfly, Caddis Worm.

3rd Year (9 *to* 10).

Autumn Term.

1. Preparations for continuing life of race or individual plants other than by seeds.
   Study of a whole plant, whose life history has been watched: the Broad Bean.
   Study of surface and underground stems: Violet, Cinquefoil, Goatweed.
   Food storage: Potato, Crocus corms, Root tubers of Celandine and Wood Anemone.
   Non-flowering plants: Toadstools and Puffballs.
2. Continue study of birds, Bird table, Residents and Migrants.

Autumn and Early Spring Term.

3. Definite gardening begins. Boys dig and prepare their own plots. Life of the soil. Cockchafer and other beetle 'grubs' and pupæ. Millipedes and centipedes. Woodlice. Simple soil experiments.
4. Non-flowering plants, Mosses, Lichens, Moulds.
5. Simple experiments with seedlings to find out the best conditions for their growth.
6. Life history of crocus.

Summer Term.

Pond life. Recognition and growth of common water plants. Water insects, e.g. 'Bloodwork,' Gnat and other fly larvæ. Water spiders. Newts.

Life in the Garden. Certain life histories. Underground food storage, e.g. Carrot, Radish.

In the later stages children's observations should become more detailed and the facts collected should be related in the form of continuous studies.

4th Year (10 *to* 11).

Autumn Term.

1. Preparation of plants for winter.
   Tree study. Form from the mass of a tree. Leaf changes and fall. Evergreens; relation to climate and altitude. Protection of deciduous trees in winter. Recognition of winter buds and interpretation of markings of twig. Simple analysis of tree form.
2. Spiders—especially the Garden Spider and the House Spider.

Spring Term.

1. Opening of buds. Different kinds of bud scales and leaf arrangement.
2. Experiments to find out how water is drawn up a plant.

Summer Term.

Study of weeds, their root and leaf systems, flowers and fruit.
Study of Woodland and Ditch.
Plant Galls.

The above scheme is augmented by the series of Nature Talks from the B.B.C., entitled *Round the Countryside*. The syllabus of these talks will be found in the B.B.C.'s Handbook. A short preparation on general lines should be made immediately before the broadcast, and a preliminary examination of specimens, pictures, etc., may be made.

Health and Hygiene.

General Observations.

It is fatal to the formation of healthy habits, and the creation in the pupil's mind of the right attitude towards health, to attempt to separate theory from practice.

Instruction in health should be related to the habits of the individual and the needs of the community.

Scheme.

In all classes hair, hands, nails, teeth, clothes (tidiness), boots, will be subjects of daily inspection as per time-table.

For milk and lunch classes must use the tablecloths provided and table manners must be taught. Milk caps, straws, papers, etc., to be placed in receptacle and classroom made tidy.

During the first three years the pupils will not be given set lessons in hygiene, but matters of health and personal hygiene will be taught incidentally and as opportunity arises.

Fourth-Year pupils will be given a twenty minutes' lesson weekly on the following :

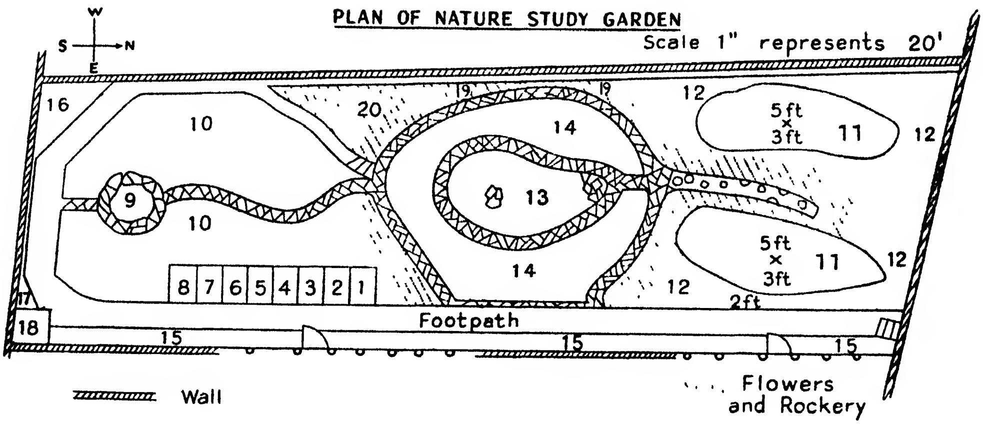
The Skin : pores and sweat glands ; soap and cleanliness.
Breathing : the lungs ; correct breathing ; colds and infection ; clean handkerchief ; value of physical exercises.
Fresh Air and Sunlight : stale air and fresh, contrast ; bedtime ; the sun (lights, warms, cleanses, cures) ; outdoor games ; artificial sunlight ; town planning ; daylight saving.
Posture : value, and marks of good carriage ; common faults, and causes ; correction of poor carriage ; walking, footwear.
Digestion : the fire in our bodies : fuel for the body ; the ashes or waste ; manners when eating.
Teeth : made for use ; value of eating crusts ; care of teeth ; school dentist.
Hair : the root ; oil sacs ; cleanliness, nits ; care of hair.
Nails : dirt and germs in ; nails of cat, dog, horse, etc. ; how to trim and clean.
Sleep : great need for ; proper conditions for sound and restful sleep.
Safety First : how to cross the road ; dangers of street corners ; riding bicycles carelessly ; hanging on to the backs of carts ; traffic lights and Belisha Beacons.

Use pictures from ' Health and Cleanliness Council.'

(*b*) A Shropshire Junior School.

Nature Study.

This is based upon a Nature Study Garden, which has been arranged for the purpose. It illustrates the modern method by which schools teach through actual experience and shows how vitality is given to the curriculum.



1. Trees planted 1937.
2. Cuttings.
3. Annuals.
4. Biennials.
5. Thinning.
6. Trenching and non-trenching.
7. Corn.
8. Insect cage.
9. Fernery.
10. Trees.
11. Bulbs and low-lying shrubs.
12. Low-lying shrubs.
13. Pond.
14. Grass.
15. Flowers.
16. Rubbish.
17. Sand.
18. Tool Shed.
19. Climbing trees and plants.
20. Birds' nesting box.

The Nature Study Garden.

As the Nature Study Garden has become the centre of outdoor activity and an essential link between the Classroom and the Countryside, a brief summary of the Nature Study Course is given.

1. *The Individual Child* is encouraged to keep his own pets and to grow his own plants at home, and judiciously to collect specimens for the Nature Tables, the Insect Cage, and the Pond. These recreational home activities of the children have proved a great success with a large group of children, including some of the retarded boys.

2. *In the Classroom* specimens are examined and an endeavour is made to make some systematic studies and to note some of the general laws of nature.

3. *The Central Nature Tables* serve as a general record of the changing countryside during the seasons, and provide a means for the continuous study of simple experiments and observation of insect and pond life.

4. *The Nature Study Garden* provides lawn, rockery, herbaceous border, fernery, shrubbery, pond, nesting boxes, and 'Nature Plots' where each year simple experiments can be made under ideal conditions (see below).

5. *The Nature Walk.* In the immediate neighbourhood there is a wealth of nature material in lanes, fields, woods, streams, and ponds. The aim of the walk is not the collection of innumerable specimens, but the cultivation of habits of observation. Preparation is made beforehand to avoid its degenerating into a hurried scramble.

6. *The Nature Study Library* contains a series of reference Nature Books for Juniors, e.g. the 'Look and Find Out' series. With the help of these the children can find out for themselves and identify many of their discoveries.

The Nature Study Course is made as recreative as possible, but at the same time it includes special studies where accuracy is insisted upon. It followed, therefore,

that when the School Garden was being remodelled an effort was made to provide it a place where simple experiments and demonstrations could be undertaken, *but* also a place of beauty in which both teachers and children could take a pride.

The site, long and narrow, presented some difficulty in layout, while recently erected buildings on one side did not make things easier.

The main features aimed at were :

1. Attractive features, pond, rockery, etc., in the right setting so far as was practical.
2. A central Meeting Place where a class might gather for a short talk.
3. All parts of the garden to be easily accessible by paths.
4. A large pond where the common pool creatures could be kept in their natural surroundings.
5. An insect cage where the life-story of common insects could be kept under close observation.
6. Different situations and aspects where rock plants, herbaceous plants, ferns, shrubs, etc., could be grown.
7. ' Nature Plots ' where simple experiments could be carried out.

During 1938 the following work was done :

Plot 1. Trees from seed, planted 1937 ; the rate of growth of the different trees to be noted during a period of four years.

Plot 2. Plants from cuttings. (Planted September 1937.)

Plot 3. Annuals : Growth, flowers, and seed, noted.

Plot 4. Biennials during second year. (Carrots, wallflowers, etc.)

Plot 5. Simple experiment in thinning and transplanting with lettuce. (Lettuce also used for feeding the silkworms.)

Plot 6. Corn and wheat, spring and autumn sowing ; oats and barley.

Plot 7. Simple experiment in good (i.e. ' deep ' in this case) cultivation. Parsnips sown (*a*) soil trenched ; (*b*) soil lightly forked.

Plot 8. Insect Cage containing cabbages—larvæ of Cabbage White—black currant bushes—larvæ of Magpie Moth—and nettles—larvæ of Tortoiseshell Butterfly.

Scheme of Work.

The course is recreative rather than formal, but at the same time special studies are made where accuracy is insisted upon. No detailed scheme of work is imposed as an effort is made to keep close to the normal experience of the children. Much of the work depends, therefore, on the specimens found in the district and on the observations made in the School Nature Study Garden.

The scheme is arranged in relation to the seasons and is concentric in method, more detail and suggestive reasons being given as the child proceeds through the school. In the junior school stage children take pleasure in collecting ; they begin to assert themselves, and to show recognition of cause and effect. Moreover they begin to take an increasing interest in living things, and the aim of the Nature Study should be to encourage and guide this interest.

Neither the scheme nor the time-table is rigid ; the amount of time given increases in the spring and summer, and depends on the interesting specimens to hand and on any special phenomena in the school pond or insect cage.

In the classroom notebooks are used and children are encouraged to sketch and register. Books of reference are essential to the course for both teacher and child to explore together. Simple experiments on germination, plant growth, and examination of different soils, are included in the course. The Central Nature Tables are a means for the continuous observation of simple experiments and

of pond and insect life; while they serve as a general record of the changing countryside.

Seasonal Course.

Spring.

Season of reawakening—catkin two kinds of flowers—germination of seeds—effect of light, warmth, water. Opening of buds of common trees—early spring flowers—collection. Continued observation of growth of bulbs. Bulbs, corms, roots in general. Growth of potato tubers under different conditions.
Insect life—life-story of a frog—May flies.
Reappearance of pond life.
Study of caterpillars on appropriate food plants in Insect Cage.

Summer.

Summer flowers—collection of wild flowers—the meaning of flower—the uses of nectar, colour, and fragrance, in attracting profitable insect visitors—interrelation of flowers and insects. Study of the plant—simple experiments to show absorption of water, loss of water, etc.—effect of light—arrangement to avoid overcrowding. Result of summer work—the filling of tubers and other storehouses. Formation of next year's buds—the making of seeds and fruits. Insect and pond life—life histories—silkworm moth—cabbage white—Red Admiral Aphis—Ladybird Bees.
Food—Self-protection—care of young. Beneficial insects—ladybird, lace-wing fly, hover fly, ichneumon fly. Summer in the pond—caddis fly larva, boatmen, scorpion, dytiscus beetle.

Autumn.

Harvest time—kinds of corn—fruits—worm-infected apples—falling leaves—time of 'fall'—exhibition of brilliantly coloured leaves collected by children—network of 'veins' in skeleton leaves. Earthwork—burrows with leaves half in—Darwin and Shropshire—his account and experiments with earth-worms. Fruits collected from various plants—kinds of fruits—uses of fruits. Seed dispersal—breaking, wings or parachutes—adhesion to animals. Fruits and seeds—what they contain. Autumnal migration of birds. Storing of food supplies (distribution of seeds).

Easter Term.

Winter studies—weather and slanting rays of the sun. Evergreens—special study and exhibition collected by children arranged for Christmas. Ever-greens and conifers—larch, ivy, holly. Deciduous trees in winter—how to recognise common trees in their winter state. Skeleton leaves—winter flowers—berries—mistletoe. Birds in winter. Dormant chrysalids—hiding place of Red Admiral and Ladybird. Hibernation—squirrel—hedgehog. Simple experiments with soil—clay, sand and loam. Growing of bulbs in fibre and in water.

(*c*) A London Junior Mixed School.

The third scheme is that of a London Junior School. Here, as in the previous schemes, the work is based upon the everyday experiences of the pupils. Here, however, the garden, which plays such an important part in the Shropshire school, is not available; but the head teacher has used the environment of the pupils to give reality to the work.

Science.

Class 1.

Improvements and Progress due to Science and Scientists.
Great Men of Science.
What Science has done for London.
How Science affects the home.

General Topics.

Air :

Takes up space, exerts pressure.
Streamlining.

Composition—

Oxygen :
Living and Burning.
Rusting and Tarnishing—Oxidising.
Galvanising and Painting.
Plating (Tin).
Stainless Steel.
The Supply of Oxygen.

Nitrogen :
Inertness, etc.

Carbon dioxide :
Properties.
Lime Water Test.
Fire Extinguisher.
Mineral Water Drinks.

Water :

Its uses. Three States.
Water Supply. Siphon.
Hard and Soft Water. Fur.
Ice, and Protection of Pipes.

States of Matter—Changes.
Expansion and Contraction.
Solids, Liquids and Gases.
Temperature and its measurement.
Conduction.

Plant life :

Germination—Conditions necessary.
Bulbs and Seeds.
Structure and Functions of Parts of a Flower.
Seed Dispersal.
Could we live without plants ?

Hygiene :

General Structure of the Body.
Functions of the chief organs.
The skin—structure, functions. Importance of cleanliness.
Breathing—Artificial respiration.
Posture—correct carriage—the feet.
Teeth—structure, use, cleaning.
Hair, nails.
First Aid.

How Science ' lends a hand ' in the home.
Building the House. Electric and Gas Appliances.
Chemicals in the Kitchen. Lighting the Fire.
Water. Washing. What happens in the Dust-bin.
Clocks, Gramophone, Radio.

IV. Encyclopædia Work.

An interesting account of another method of increasing the informative content of education was received. This was described as Encyclopædia Work, and the following notes were sent by a teacher in a London junior school where it is practised. It will be obvious that there is a similarity between this method and the Library Scheme used by Sanderson of Oundle.

The work has proved to be a very real contribution to the new approach in education, enriching the teacher's technique and developing the child's initiative. The possibilities are enormous, and the teacher who is eager to experiment enjoys the happy privilege of descending from a high and distant throne, to enter into the personal life of each individual. To-day he can be the most vivid personality in the life of each child.

Factors.

The introduction of encyclopædia work in any school depends chiefly on the following :

(1) A progressive headmaster who has a sympathetic, helpful approach to both staff and boys.

(2) Enthusiastic teachers with an experimental bent, with the ideal discipline of gentle restraint, rather than fearful rigidity.

(3) Elasticity of curriculum to ensure the beneficial fusion of the subjects on the school time-table.

(4) The child's easy access to diverse reference books.

Research Mind.

In any undertaking of merit the underlying factor is sincerity of purpose. The teacher, in the early stages, must strive to foster in the child the *Research Mind*, so that the child's work is always sincere, and not merely the reproduction of a teacher's lesson. Remember that the young child's first efforts at self-expression are like a man's first speech—usually a poor show. There must be continual encouragement, and the child's original manuscript must be treated with respect. It is his work—he is a creative artist in the embryo, seeking to express his thoughts in some direction that holds his interest. Condemnatory marking dries up the fountain that probably would have gushed freely, and so it is essential to allow the young child to write copiously and unreservedly on things that may seem strange to the adult mind. Several little boys of eight were determined to write on such topics as whooping cough, flies, diseases, scooters and furniture. This unfettered choice forms an excellent beginning and soon an encyclopædia takes an alphabetical form ; and slowly the inclination comes, on the child's part, to consult other reference books to supplement his own ideas. At first there may be a paucity of ideas—but as this is natural the teacher should not be discouraged. With smaller boys, it is more satisfactory to compile one big class encyclopædia ; but later, as a natural development, the older boys make their own, or undertake to be responsible for one letter, say A, B or C. The boys begin to specialise in their research ; one boy may do the internal combustion engine, while another writes on primitive houses. Knowledge grows in school and out of it, and after the correct stimulus comes the response. The boy must feel that he is doing something that is of great use, and not a scholastic exercise that is doomed to fall under the marking of the blue pencil and sink into the ignominy of the waste-paper basket. The beauty of the encyclopædia work lies in the fact that the continual practice in self-expression develops his flow of English, frees his style, and enriches his knowledge in a natural manner of the true student. The child is browsing in those early pastures so dear to the heart of any human with a sense of awareness. He is a gleaner, and is learning how to use books and assimilate knowledge.

Practical Suggestions.

(1) Instil the *library habit*. Form a good school library of science, history and geography. It is of inestimable value, however, to encourage the boys to go to the Public Library, tender a ticket and select a book in their own time. At this school the majority of the boys use the Public Library as easily as an adult. This factor cannot be over-emphasised.

(2) Encourage every pupil to amplify his written work by pictures, maps and diagrams of his own choosing. There are so many excellent pictures and photographs available nowadays, that even in the poorest areas children can compile beautiful ones. They lead to discussion, and it is surprising how much children learn when they want to know.

(3) Regard the encyclopædia as the child's personal possession, not a show piece, but an ' honest to goodness ' effort that must be consulted and used.

(4) Disregard the early crudity of the work, for therein lies its strength. One must bear in mind that primitive art was crude, but it held the soul of the future artist.

V. Observations on the Junior School Schemes.

(1) *History.*

An examination of these syllabuses illustrates both the method of approach and the scope of the work attempted in the schools. In relation to the history, much of what Mr. Wells suggested is to be included, but not in the form of definite instruction on the particular section or aspect of history. Thus in none of the syllabuses does there appear a reference to ' The general idea of break-up of Christendom and the appearance of Sovereign States.' Similarly, while the life of Mohammed appears in each, there is no attempt to trace the Rise and Growth of Islam, though further references to this subject would doubtless be made when the Crusades were studied or the Revival of Learning was under discussion. Other sections, e.g. ' The coming of the Aryan-speaking peoples,' are also omitted. One observation should be recorded. The idea that history as now taught in the schools is a matter of ' 1066 and all that ' is not supported by the schemes submitted. Neither is teaching mainly concerned with wars and kings, though some references to both of these are necessary to enable the pupils to understand the reasons for and the nature of the resultant changes in the lives of the people and to appreciate their influence in the creation of present-day conditions.

An examination of these schemes, however, reveals a disposition to refer almost every fact to Britain or the British Empire. In view of the demands likely to be made in future upon the people of this country for an understanding of the conditions and policies of the people of other countries and the possibility of the need for co-operation with them, the Committee think that an extension of the area of comparison and contrast, even at this early stage in the educational course, is worthy of consideration.

In each of the returns received the period devoted to history was said to be 1 hour per week. It will be recalled that the length of time suggested for the subject was 2½ hours. The increasing importance of the subject and the desirable enlargement of its scope indicate that 1 hour per week is too short a period if the work is to be effectively taken. The Committee suggest, therefore, that more time should be devoted to it ; they think the present amount of time might with advantage be doubled.

(2) *Geography.*

In Geography, one or other of the schemes included all that was suggested, with the exception of Geology. The time devoted to it was generally 1 hour, which is the same as that indicated by Mr. Wells.

The syllabuses were subsequently submitted to a University Lecturer in Methods of Geography Teaching, who was of the opinion that they were excellent, but they should not be commenced before the age of 8 years. In reference to the first he thought there was insufficient outdoor work included and that the syllabus for the fourth year was too abstract and ambitious.

These opinions will very possibly be shared by others. But the fact of major importance for the purpose of the Committee is that schemes actually in use in schools afford evidence that the proposals contained in this section of Mr. Wells' '*Informative Content of Education*' are practicable and the work suggested is already being attempted.

(3) *Science.*

In Science there were many omissions. None of the schools made any attempt to indicate the Succession of Living Things in Time ; to deal with Geological Ages ; or to give general ideas of Ecology and Evolution. Neither were the sections which included Human Reproduction, Chief Diseases and Enfeeblements, found in any of the syllabuses received. One scheme indicated the approach to physics and chemistry and provided the opportunity to deal with the elementary history of invention and discovery through the biographies of great scientists ; the others dealt with animal and plant life including reproduction, and with personal hygiene ; but the whole scheme outlined by Mr. Wells was nowhere attempted. The time devoted to the subject was 1 hour.

The syllabuses reproduced, together with the foregoing summary, were subsequently submitted for his observations to a University Lecturer in Methods of Science Teaching who has had wide experience in both the teaching of science and the examination of syllabuses in this subject. His comments were as follows :

'I think it is highly improbable that *any* junior school would be attempting to deal with any of the things Mr. Wells suggests as suitable for this stage of instruction—except, perhaps, incidental references to, for example, " the working of our bodies " (i.e. levers in the body, respiration and digestion).

'Though in full sympathy with Mr. Wells' aims and ideals, I do not myself think that it would be wise to deal with material as general as, for example, " the processes in the prosperity, decline, extinction and replacement of species " with children of 7 to 11. Concepts empty of content have little educative value. The difficulty that teachers find at this stage is not to show their pupils what is meant by the evolution of species, but to tell them how any single plant or animal grows from its seed ; i.e. they try to teach how the chicken comes from the egg, rather than how chickens themselves came to be as they are.

'I would be in favour of letting children of 7 to 11 play with scientific materials and apparatus, keep pets and grow flowers and vegetables, browse among a good library of suitable books, play with Meccano sets, visit factories, etc., make models and carry through simple projects requiring co-operative planning and work. But to try to deal with generalisations of wide sweep at this age is to try to grow flowers directly from seeds (like those Japanese flowers made of paper, which one puts in water for a few minutes) ; or, if you like, it is trying to " mow the moss and to reap the green corn."

'So the fact that so little of what Mr. Wells suggests is done is due, not only to the short time (certainly *much* too short) available to children in Junior Schools for scientific studies, but also the realisation (justified, I think) that this generalised and philosophical approach is not suited to juniors.

'Of course, one could reveal a different state of affairs if Senior Schools (11 to 15) were being discussed. And, in my view, Mr. Wells' suggestions would apply much better to these.'

The Committee of the Science Masters' Association, after commenting upon the suggested science scheme for pupils below the age of 7, observed in reference to the section given in Grade B (ages 7 to 11) : ' Although some of the details which are scheduled may be taught didactically and with good effect, the generalisations come too soon. Children of this age are hardly able to distinguish between chemical and physical actions, much less to bear the " foundations of pure physics and chemistry." Such concepts involve classification of phenomena which come easily to the trained mind of an adult but are too remote from the thoughts of a child.'

After consideration, the Committee were of the opinion that there does seem to have been rather too much in Mr. Wells' requirements here ; and they were certainly rather alarmingly phrased. Some at least of them, however, are likely to be, and evidently should be, carried forward.

General Remarks.

The traditional treatment of the curriculum in elementary schools was to deal with subjects separately. Recently, however, greater recognition has been given to the need for thinking of the curriculum as a unit and not in terms of individual subjects. Certainly it is not possible to divide the curriculum into self-contained compartments, and the reasons for the separation of Geography and Science are not apparent. The former has much in common with the latter, which arises out of the study of nature, whether animate or inanimate, and of some of the works of man. From the information before them, therefore, it appeared to the Committee that what seems to be needed is a better recognition of the interrelation of Geography and Science, rather after the pattern of Huxley's *Physiography*, but with greater attention to life in relation to space and time, and how it is influenced by scientific discovery and invention. In like manner, some aspects of Geography are closely related to History. A reconsideration of each of these subjects and their interrelations offers a great opportunity for removing the restricting effect of a classification which, for an active study of the whole environment, is artificial and unhelpful.

SENIOR SCHOOLS.

I.

Last year the Committee expressed the opinion that further investigation was desirable to discover how far the actual teaching in the schools, regardless of the terminology employed, does cover the various sections of the subjects to which reference is made in the outline of an *Informative Content of Education*.

With this end in view, an attempt was made to obtain copies of syllabuses in use in the senior or central schools from which, it will be recalled, was received the best response to inquiries based on Grade C of the *Informative Content of Education*.

Several of these syllabuses have been received. One was from the head mistress of a Stafford school whose replies to last year's questionnaire were as follows :

(a) *History*. ' Practically all is taken in one syllabus or another, with the exception of " detailed study of European history " as mentioned in Mr. Wells' speech. All of it is taken in so far as the sections make contact with English or Imperial history.'

(b) *Geography*. ' Taken almost exactly as indicated except that the Geology side is only simply touched upon.'

(c) *Social Mechanism*. ' " A short history of communications and trade " and " the history of innovations in production and manufacture " are taken, but they are only very inadequately covered, and the " Role of Property and Money in Economic Life " is only dealt with as it affects the other sections of the subject.'

The detailed scheme used in that school is very interesting and suggestive. The syllabuses in Geography and History are arranged in two courses, the 'A' for the brighter pupils and the 'B' for those not so bright. The former are reproduced below. Since they indicated in some measure both the methods of approach and the aims of the scheme, the head teacher's notes for the guidance of class teachers have also been included.

History.

I. *Aims.*

(1) To awaken and train an intelligent interest in the past and a general desire to emulate the noble and scorn the ignoble; to awaken and train patriotism of the truest type and a keen sense and love of justice.

(2) To develop a general feeling of indebtedness to the benefactors of the past, a loyalty towards those in authority, patriotism towards one's own country, compatriots and co-workers (emphasise class and school loyalty, necessity for 'playing the game' and for true and earnest work on the part of *every* member of the community); necessity for 'administration,' 'capital,' and 'labour' in the outside world—the interdependence of them all and the utter futility of the attempt to destroy any one of the three.

Emphasise also the responsibility of the present generation,

(*a*) to the past;
(*b*) to the present } most essential.
(*c*) to the future }

(3) To provide a reasonable basis for the understanding of national affairs and the development of true citizenship, and to lay the foundations for intelligent voting in the future.

(4) To give a reasonable survey and understanding of the struggles, changes and processes by which the England of to-day and the British Empire came into being.

(5) To stimulate a general interest in and give a conception of the British Commonwealth of Nations, its characteristics, functions and government, the responsibility of each part of the Empire, and the interdependence and responsibilities of the Homeland and the Colonies.

(6) To develop powers of judgment, reasoning, imagination and memory and an appreciation of the relics of the past in our own land and elsewhere.

(7) To kindle a lively interest in all useful exploits, adventures and invention as well as in current events.

II. *Suggestions on Method.*

(1) Follow closely the lines laid down in the syllabus so that at the end of the course the contents have been covered as fully as possible.

Divide each year's work into three definite terms' work (allowing some time in third term for revision); enter each term's scope in the space set aside in the Record Book.

Expand each term's work in detail on the lines on which you intend to teach, having *one* central theme—the 'Project.'

Use this expansion as the synopsis on which to write detailed notes of lessons, which should, at their best, indicate methods of presentation, apparatus to be used, etc.

(2) Use the best books available on any heading for class work and in the 'A' sections; in 'B' sections work must be mainly oral lessons and expression work.

Supplement the subject-matter, illustration and description by one's own reading from the more prominent and fuller histories of the period, also by reading appropriate and typical extracts to the class where possible, showing original matter (e.g. copies

of charters, etc.) ; allow brighter girls to read more about any one subject in their own time ; make historical visits wherever possible, and use all available devices which may serve to widen the scope of the teaching.

Be careful to make all teaching very thorough, definite and attractive, and be sure that the presentation is fully understood by the class.

(3) Base teaching on ' Cause and Effect ' and establish the axiom that similar causes lead to similar effects ; teach from the past the lessons of the present and future.

(4) In subjects of controversy avoid personal bias ; give both sides of the question as fully and accurately as possible (where suitable to the age of the child), then leave girls to judge for themselves. If your teaching is adequate they should be able to form a fair estimate.

(5) Make ' personalities ' and ' events ' *live* as far as you can. All teaching must be visual in the girls' imagination if possible. Do not teach bald, dry facts.

' Every step in *knowledge* should be accompanied by practical application and illustration.' (Board of Education Suggestions.)

(6) Preserve a very accurate chronology in all your teaching ; do not trouble the girls with minor, insignificant dates or events of only transient importance, but be sure that they know the landmarks and the setting and characteristics of each typical period as well as the most important dates.

(7) Use as many *forms* of illustration as possible (also expression work), maps, charts, illustrations, models, projects, notes (' A ' sections only), extracts, exercises, co-operative illustrations, visits, albums, dramatisation, friezes, etc., etc.

(8) Remember that good results follow only from keen interest in the work of both teacher and taught, and a full knowledge and thoroughly detailed preparation on the part of the teacher.

(9) In every oral lesson build up a systematic blackboard summary as the lesson proceeds ; use this at the end for revision, and, if desirable, as the basis of the record in the girls' notebooks (only ' A ' sections) ; *or* the girls might make their own digest of the lesson under the headings of the summary or expand fully the most important heading, etc., etc.

(10) ' A ' divisions only : Use the ' study ' method freely but be quite sure that work set is very definite, that it *can* be done from books supplied and that the results of the study are tested (preferably by written exercises). Avoid all laxity and haziness in ' study ' work and be quite sure that the teacher knows *beforehand*, in detail, the contents of the books placed in the hands of the class.

(11) With discretion the class may be divided into groups for studying one particular point each, to contribute towards a whole ; but this type of work requires very careful organisation and preparation on the part of the teacher to avoid waste of time and to make the study really effective.

' Teachers' chief work is to teach the children to teach themselves.' (Board of Education Suggestions.)

(12) Make as much use as possible of the literature dealing with the period—especially when dealing with social history (great personalities, vivid incidents). These give the atmosphere of the time far better than most modern illustrations can do.

(13) Essential facts *must* be learnt and constantly revised as well as important dates (dates of important kings and queens are quite useful landmarks). Study to be tested throughout the year by written exercises (sometimes short answers, sometimes cursive), also by discussions and debates. All this is particularly for ' A ' divisions. As a rule the best way of testing ' B ' pupils is by means either of short questions requiring very short definite answers *or* by asking for description of any one point in a paragraph.

Let *all* illustrate notebooks by sketches, cuttings, maps, etc., and unless there is

a definite reason (e.g. infection) for not doing so, let each girl keep her own history album throughout the school.

Use Time-charts very frequently ; these must be *visually* accurate as regards time.

'Who ? Where ? When ? and Why ?' should be the keynotes to History Study.

(14) In 'A' divisions note the importance of frequent and adequate oral lessons to prepare the way, to gather up threads, to supplement study, etc.

Scheme for 'A' Division.

First Year.

1st Term.

Project : 'Britain and the Britons.'

(1) *Introduction*—to be dealt with generally.
- (*a*) The Old and New Stone Age—its people, habits and characteristics.
- (*b*) The Bronze and Iron Ages (in Britain specially).
- (*c*) The Oldest Civilisations—Babylonian—Egyptian (cf. Bible History) —Greek and Roman.
  The people—characteristics—reasons for renown. Traces of their civilisations to-day.

(2) *Britain as a province of the Roman Empire.*
- (*a*) Rome and the Roman Empire—its growth, extent, characteristics.
- (*b*) Britain as a Roman Province—advantages and disadvantages—traces of the Roman occupation seen in England to-day—camps, coins, roads, arches, buildings, etc., etc.
- (*c*) The Struggle of Christianity—its introduction into England.

2nd Term.

Project : 'Early England.'
- (*a*) The Recall of the Romans—followed by the English Invasions—results.
- (*b*) Influence of the English people—incentive given to Christianity by Pope Gregory and Augustine—general organisation of worship—building of churches, schools, monasteries.
  Architecture and Art of the period.
- (*c*) The coming of the Vikings—the growth of Wessex and English Nationality.

3rd Term.

Project : 'Norman England.'
- (*a*) The Norman Conquest ; organisation of feudalism and the consequent strengthening of the English Nation—centralisation of the Monarchy—effects on life—language, customs, architecture and status of England.
- (*b*) England and France.
- (*c*) Social conditions of the period—blending of various races—Domesday Book—agricultural conditions and the influence of the Manor.

N.B.—The two-fold aspect of feudalism—protection and service—effect in welding people into a national whole.

Second Year.

1st Term.

Project : 'Monastic Life in England.'

N.B.—All other work to be general and subsidiary.

(1) The State and the Church—relative power under the Normans and Plantagenets—conflicts and settlements.

(2) Monastic Life—its growth—importance and effects—description and plan of Monastery.
(3) Rise of Town Life—influence of Monasteries—trade and industry.

N.B.—England's European status under Henry II.

Note following points :

1. Rise of Parliament and Self-government—struggles and stages—Magna Carta.
2. Mohammedanism and England's part in the Crusades.
3. Life in the Middle Ages—the Friars—Universities—methods of justice—transit and trade under the later Plantagenets.
   Conquest of Ireland and Wales—attempted conquest of Scotland.
4. The Hundred Years' War—effects in England—Black Death and Peasants' Revolt—*n.b.* effect on monasteries.
   Decline of the power of the Church.
   Chaucer's England.
5. The Wars of the Roses and the dawn of modern England.

2nd Term.

Project : 'Tudor England.'

The Tudor Dynasty.

(*a*) The working and effects of Tudor Despotism following the Wars of the Roses—General Settlement effected by Henry VII—
  (*a*) abroad ; (*b*) in England.
(*b*) Rise of the New Nobility—effects and influences. Henry's methods of
  (i) administration ; (iii) finance ;
  (ii) dealing with impostors ; (iv) trade.
(*c*) The Renaissance—the fall of Constantinople—causes and effects on
  (i) learning ; (iv) trade, trade-routes, and adventures.
  (ii) the 'Arts' ;
  (iii) industry and invention ; (v) religion.
  Teaching as far as possible to be centred round the Heroes of Learning, Art, Science, Invention, Exploration and Religion (English and Continental).
(*d*) The Reformation—a phase of the Renaissance—causes, leaders, progress and results.
  (i) in Europe ; (ii) in England.
  Attitude of the successive Tudor sovereigns ; results of changes.
(*e*) Shakespeare's England—Elizabethan Drama. 1485 to 1603.

3rd Term.

Project : 'The Sea-Dogs of England.'

(1) Elizabeth's policy and methods
  (*a*) in England ; (*c*) in connection with Scotland.
  (*b*) in connection with Spain ;
(2) The beginnings of English naval supremacy.
  (*N.B.*—Bull of Alexander VI Borgia and its effects.)

Advance in Ship Construction—dock construction, etc. ; impetus given to further naval adventure and exploit
  (*a*) by Renaissance theories ; (*b*) by Defeat of Armada.

(3) Tudor Heroes of the Sea.

N.B.—Great advance made in :

(*a*) Status of England as a political power.
(*b*) Methods of life in the country—dress, customs, pursuits, amusements, luxuries (*n.b.* sea voyages), architecture (domestic and national), adventure, etc.
(*c*) Trade and industry—exploration—methods and dangers in transit, etc.

Third Year.

1603—*Napoleonic Wars.*

1st Term.

Project : ' Cavaliers v. *Puritans.'*

Work to deal with the following points :

(1) Difficulties with which James I was confronted on his accession.

(*a*) In England—religious parties—plots, etc., *n.b.* effect on Empire Building—national religion—the Bible, etc.
Build lessons round the great adventurers where possible.
(*b*) In Ireland.
(*c*) In Europe—outbreak of the Thirty Years' War, etc.

(2) The Conflict between King and Parliament—causes and effects.

(*a*) Trace main steps in national representation and government : from Magna Carta to Tudor despotism—*n.b.* reasons why, although the people submitted to the Tudor despotism yet they would have none of Stuart despotism (changes in the succession—in the prosperity and life of the country—in the attitude of the people and their outlook and scope—in the form of the despotism—in the personalities and accumulated wealth of the monarchs).
(*b*) Conflict under James I—his difficulties—causes of the conflict—fatal results of the Hampton Court Conference—progress and effects of the struggle.
(*c*) The ' heritage ' of Charles I (*n.b.* particularly the ' personalities ' of each Tudor and Stuart monarch—has so much to do with the failure or success of each—make teaching as vividly pictorial as possible at all stages—see suggestions on the subject—this cannot be overdone).
The attitude of the people on his succession—difficulties confronting him augmented by his foreign alliance and its results—steps in the progress of the struggle leading to the attempted arrest of the Five Members and the outbreak of Civil War (only the decisive landmarks and essentials to be studied).
Group the teaching of the struggle as far as possible round the outstanding people of the time, e.g. Laud, Wentworth, Pride, Prince Rupert, Cromwell, etc.

(3) The Establishment of the Commonwealth—contrast Stuart despotism with Cromwell's despotism—causes of failure of the latter—Cromwell's conception of

(*a*) government and representation ; (*b*) empire.

Take these very simply but emphasise his new outlook (typical of the times) and his methods of trying to achieve his aims.

2nd Term.

Project : 'Stuart England.'

(1) The ' Glorious Revolution '—opposition in

(*a*) Scotland ; (*b*) Ireland ; (*c*) the Continent.

(2) The War of the Spanish Succession—causes and results. Marlborough and his achievements—the Treaty of Utrecht and its effects on Empire building.

(*N.B.*—In dealing with wars always treat them on quite general lines—never pursue battle after battle—deal with causes—scene of operations—main decisive episodes—results. Group all the teaching round the outstanding personalities.)

(3) England in Stuart Times.

(*a*) Religion.

(*b*) Conditions of life—dress—customs—amusements—houses, etc., etc.

(*c*) Adventures—enterprise and empire building.

(*d*) The Great Plague and Fire.

3rd Term.

Project : The ' Old Empire.'

(1) *Introduction.*

The Early Hanoverians (to be taken on quite general lines):

(*a*) Walpole and the beginnings of ' Cabinet ' Government.

(*N.B.*—Characteristics of the early Hanoverians and the opportunity these afforded for the development of the Cabinet form of government.)

(*b*) Continental affairs and the '45.

(2) William Pitt and the Seven Years' War :

(*a*) On the Continent—of little importance.

(*b*) In India
(*c*) In Canada } Vitally important in the History of the Empire.

(*N.B.*—Position of British Empire in India and Canada before and after the War.)

1763—the climax of the ' Old Empire.'

(3) George III and his ' Be-King ' policy—collapse of the ' Old Empire.'

Position of England as an Imperial power in 1783—Adam Smith's theories—lapse in Imperial policy.

(4) England in later Stuart and Early Hanoverian times—form of government—social conditions and customs—Wesley revival—agrarian and industrial revolutions—new methods of agriculture—industry—transit, etc.

(5) The French Revolution and the Napoleonic War (only to be introduced as starting point for next course).

Fourth Year.

' The 19th Century and After '—to be taken on very general lines, emphasising Social and Imperial Development.

1st Term.

Project : 'The Industrial and Agrarian Revolutions.'

(1) *Introductory.*

(*a*) The French Revolution and the Napoleonic War—causes and effects, particularly on England.

(*b*) The aftermath of the War (cf. Modern Times)—trade depression, etc.

(2) *The Agrarian and Industrial Revolutions*—revise details.

(*a*) Notice how war intervening for the time shelved but really increased the difficulties arising from these two movements (compare with the European War and the results of the highly mechanical age in which we are living and the consequent overproduction and lack of work, etc.). The rise of the factories—introduction of specialised labour—machinery, etc. (You cannot do better than read extracts from Adam Smith for these—they are very simple and very clearly stated, and help to emphasise the points to be made.)

(*b*) Scarcity of Work.

(*c*) Spread of vagrancy and crime.

(*d*) Necessity of new impetus in Imperial policy—the Convict Settlements, etc.

(*e*) Reforms of the 19th Century :

(i) Franchise and Legislation.
(ii) Poor Law.
(iii) Workers' Welfare—trade unions, etc.
(iv) Tariff.
(v) Science and Medicine.

2nd Term.

Project : The 'New Empire.'

(1) The 'New Empire'—exploration, extent, settlement, new methods of Imperial policy (*n.b.* 'Wakefield' system, etc.) and government; evolution of Colonial Self-government (on very general lines).

(2) The Empire To-day—'The British Commonwealth of Nations'—significance of title, etc.—extent—individual colonies, etc.

3rd Term.

Project : 'The 19th and 20th Century Inventions.'

(1) General inventions of the 19th and 20th Centuries.

(2) Trade of the late 19th and early 20th Century—position and rivalry of England—Germany—U.S.A.—Japan—China, etc.

(3) The Making of 'Modern Europe.'

(4) The great European War—causes and results—note inventions arising from the dire necessity of war.

(5) The Aftermath of War (cf. Napoleonic Wars).

(*a*) Poor Laws and Relief.
(*b*) Establishment of Labour Ministry and its work.
(*c*) Proposed Labour Camps ; etc.

(6) The 'New Empire' and the 'League of Nations.'
The value and strength of Diplomacy and the dismal waste and devastation of War (*n.b.* loss of life—hardships, diseases, etc., during active period—ill-feeling—discontent—trade disorganisation and depression—poverty—struggle in aftermath—consequent artificiality of prices—conditions of life, etc.).

(7) The 'League of Nations'—its objects, powers, achievements, hopes and organisation.

N.B.—It may not be possible to cover all points in 3rd Term. Do what time permits and make a reasonable choice.

Geography.

I. *Aims.*

(1) To train an intelligent interest in the life, customs, etc., of the peoples of the world ; to give a general and detailed (where possible) knowledge and conception of the pupils' homeland, the countries beyond the seas and the world they live in.

(2) To give an accurate idea of the great regions of the world :

(*a*) Position and population
(*b*) Build
(*c*) Climate
(*d*) Productions—animal, vegetable and mineral
(*e*) Industries
(*f*) Communications and intercourse
(*g*) Internal and external trade
(*h*) Government and civic life

} of each region studied.

(3) Comparisons and contrasts should be drawn between countries wherever possible, e.g. between such populations as those of

(*a*) China ; (*b*) England ; (*c*) Switzerland ; (*d*) Japan ; etc.

Differences and similarities in population are largely the results of geographical factors and conditions and these should be emphasised wherever possible.

(4) To give an accurate knowledge of the relative position of areas studied, means of reaching the same from the Homeland, etc., so that in after life pupils may be able to take a reasonable and intelligent interest in news from abroad, etc.

(5) To train the powers of reasoning (most important)—imagination and discrimination, visual imagery, etc. ; in 'B' divisions, rely very much indeed on forming an accurate and typical 'visual' image of any country or area studied.

(6) To give a general idea of the great natural phenomena and their influence.

(7) To train pupils in memory (including map-memory), study, construction, etc.

Notes from Board of Education Suggestions.

Older pupils should be able to draw *from memory*, *rapidly* and with fair accuracy, sketch maps to illustrate special points, and should be able (i) to fill in outline maps correctly ; (ii) to calculate distances from scale.

II. *Suggestions on Method.*

(1) In all teaching lead from 'cause' to 'effect'—make work as deductive as possible ; do not teach unreasoned fact.

(2) Use every means available to awake, increase, as well as to maintain, the interest of the pupils ; e.g.,

(*a*) well-chosen, descriptive quotations from actual travels, poems, etc. ;
(*b*) pictures of all types—particularly coloured, typical pictures ;
(*c*) illustrations issued by P.M.G.—Colonial headquarters, etc. ;
(*d*) "Tourist" books and illustrations, etc., issued by shipping offices, railways, etc.—always available at fall of the year ;
(*e*) coloured illustrations made by class (co-operative work) or mistress ;
(*f*) all types of statistical diagrams of a pictorial type—must be bold and arresting ;
(*g*) models of all types to show

(i) relief ;
(ii) typical scenes ;
(iii) typical costumes.

N.B.—Do not spoil the effect of good illustrations by having them

(i) too crowded ; or
(ii) too 'permanent' (i.e. changed rarely).
(iii) arranged unmethodically.

Note the *different* means of keeping many and varied illustrations at hand and in sets easy to study.

It is a mistake to crowd one's walls indiscriminately for a whole term at a time.

(3) Do not weary of repeatedly applying 'world principles.' Fundamentals *must* be well grounded.

(4) *Lead and Train* girls to find out everything possible from map ; study on systematic lines (not by haphazard map-reading), also general book study, etc. ; but be careful to lead thoughts and study into definite channels by careful questioning, guidance, etc. Never let children grope in the dark.

(5) In any map drawn insist upon *one* line of latitude and *one* line of longitude *at least*, so that there may always be 'world localisation' to give the keynote to any study. In vast areas, confine maps between *two* lines of longitude, to give an accurate idea of world position *and* extent.

(6) Keep weather charts, temperature charts, diagrams, maps, records of all kinds, albums, etc., and anything which aids in awakening interest in natural conditions (e.g. records of sun's altitude by means of a shadow pole in the playground ; or any other piece of practical work you can attempt).

(7) As much map-drawing as possible should be done by each class ; *but*

(*a*) do not let girls waste time drawing outlines ; supply these where possible ; otherwise let pupils trace outlines and fill in necessary details.[1]
(*b*) do not overcrowd maps—have purpose clear and unconfused.

(8) Train pupils in use of 'survey maps,' where suitable ; atlases (indexes of same, etc.) ; reference books available.

(9) Plan any useful visits, if possible, to encourage first-hand enquiry—surveying or map work.

Use home district to throw light upon any subject taught. Note also

(i) labelled goods in windows, etc. ;
(ii) current events ;
(iii) methods and routes of transit, etc. ;
(iv) details of 'current' exploration and adventure ;
(v) literature of shipping companies, etc.

Much information *re* industries, etc., may be gleaned by girls by noting printing, etc., on motor traffic passing through ; commodities, source, destination, etc.

(10) Make special note of :

(*a*) Meridian of Greenwich.
(*b*) Calcutta (roughly 90 deg. E.).
(*c*) Date-line (180 deg.).
(*d*) New Orleans (90 deg. W.).

(11) In dealing with areas producing the same vegetable products, carefully note times of harvest and study possibility of a continuous supply throughout the year.

[1] (1) An outline cut-out used in connection with loose sheets is very useful and economical and can be used for any type of map. If loose sheets and cut-out are fastened by means of a paper-pin, a complete series is at hand for reference at any time on any special country or area.

(2) Marking any special features, e.g. industries, railways, etc., on tracing paper and superimposing same on a physical map.

(1) above has distinct and obvious advantages over (2).

(12) Try to express climate by range of temperature and amount and period of rainfall.

(13) It is not essential to follow any books in every detail—*plan* the work in conjunction with the book and let the book fit in with your plan ; use books freely (often teachers and pupils using them together) and be constant in emphasising and training map-study on ' cause and effect ' lines.

(14) See that each class masters ' world principles ' ; then study and deduce as much as possible from the map by questioning, etc. Attempt any exercises in text-books suggested and frequently set others of varying types.

(15) In every lesson make a very carefully planned blackboard summary of the chief sections and sub-sections of the subject matter taken ; let pupils supply the information by carefully graded questions. See that the summary is in good form. This summary may be used :

(i) to revise at the end of the lesson ;
(ii) as digest for notebooks ;
(iii) as skeleton for pupils to expand in notebooks.

Scheme for ' A ' Division.

First Year.

Scope.

All teaching to be on *general* lines ; at the end of the year girls should have a clear, general conception of the ' Old World.'

1st Term.

(1) Some fundamental geographical principles governing the subject.

(*a*) Wind systems and currents.
Rainfall, etc. (very simply and generally).
(*b*) Latitude and Longitude—Zones and Vegetation Belts—populations and industries—types of climate—maritime and continental.

N.B.—Geographical axiom—' Altitude compensates for latitude ' ; its meaning and significance, e.g. Switzerland.

(2) Eurasia—generally.

(*a*) World position and extent—relief (' Regional ').
(*b*) Climate and population—homes, habits, customs, etc.
(*c*) Productions—animal, vegetable and mineral.
(*d*) Industries.
(*e*) Trade, commodities and markets.
(*f*) Transportation and routes.

2nd Term.

The following ' regional ' divisions of the continent ' Eurasia '—treating each division on the lines (*a*) to (*f*) above.

(1) The Great Eurasian Plain. (*n.b.* (*a*) British Isles a part ;
(*b*) Trans-Siberian Railway.)
(2) The Mountain System of Europe and Asia (*n.b.* Trade Passes, etc., e.g. Khyber Pass, Simplon, St. Gothard).
(3) Mediterranean Region (*n.b.*, includes N. Africa).
(4) India, China and Japan.
(5) British Isles (most in detail).

(i) World Position as determining its pre-eminence :
(*a*) as a sea-power ; (*b*) as a commercial power.

(ii) Extent and population—important as affecting
  (a) its development as an industrial rather than an agricultural nation;
  (b) its development as an Imperial power—importance of 'colonies' as an outlet for surplus population, surplus products, etc., and as source of necessary supplies of raw materials, foods, etc.

(iii) General build—climate—productions—trade.

3rd Term.

(1) Africa—under headings (a) to (f) (page 517).
  (i) The Mediterranean Coasts (European and African) and the Nile Valley.
  (ii) The Sahara.
  (iii) Central Africa.
  (iv) The Peninsula.

N.B.—The Cape to Cairo route.

(2) Australia and New Zealand, in broad outline only, on lines (a) to (f) (page 517).

(3) General Revision of Year's Work.

Second Year.

Scope.

At the end of the year the girls should have a clear, general conception of the whole of the New World and its international trade, internal trade, etc., treated on lines given in the syllabus and suggestions.

1st Term.

Revise 'world principles' and emphasise these throughout the course constantly.

North America.

Outline of discovery, etc.

(1) Introduction.—Treat whole region generally (a) to (f) (page 517).

(2) The four great Natural Regions—each treated as (a) to (f) (page 517).
  (i) The frozen North.
  (ii) Eastern and Highland System. *N.B.*—Effect on early colonisation (cf. Cecil Sharp's 'findings').
  (iii) The Great Central Plains.
  (iv) The Western Mountain System and the valleys between the 'Rockies' and Coast Ranges.

(3) The great River Valleys.
  (a) St. Lawrence and the Great Lakes. (b) The Mississippi.

(4) The C.P.R., Airways, etc.

2nd Term.

South America.

(1) On same lines as above—generally, (a) to (f) (page 517).

(2) The main 'Natural Regions' (a) to (f) (page 517).

(3) The Great Amazon Valley; resources, etc.

(4) Revision of North and South America; comparison and contrast where desirable.

3rd Term.

Central America and the West Indies.

(1) Treated generally, (a) to (f) (page 517).

(2) More detailed study of
  (a) Central America and Panama Canal (take the latter in fair detail).
  (b) The West Indies.

(3) General Revision of Year's Work.

Third Year.

Scope.

At the end of the year the girls should have a *detailed*, accurate knowledge of the British Isles and particularly England and her world trade.

Treat on lines suggested.

1st Term.

(1) British Isles—generally—treated as (*a*) to (*f*) (page 517).
(2) Further *detailed* study of
 (*a*) Ireland on lines (*a*) to (*f*) (page 517).
 (*b*) Scotland " " " " (page 517).

2nd Term.

Detailed study of England, on lines (*a*) to (*f*) (page 517).

3rd Term.

England's World Trade.

(1) Conditions in the Homeland necessitating and facilitating the development of England as a commercial country.

Her home industries—reasons for localisation and development of the same (*n.b.* change of 'localisation' and 'shifting' of centres—reasons for same—industrial revolution, etc.)—methods and conditions prevailing in the most important industries—regions of supply—ports—markets and routes.

(2) England's Near Neighbours—important products and intercourse—industries—routes and means of transit.

(3) England's overseas trade. Chief imports and exports—markets and routes (*n.b.* possibility of a continuous supply throughout the year of chief vegetable products (cf. 20 years ago))—means of securing same.

Fourth Year.

Scope.

At the end of the year the girls should have a *detailed*, accurate conception of the world, particularly of the British Empire and the great 'highways' of the world.

Treat on lines given in syllabus and suggestions.

1st Term.

(1) Geographical forces and their work (chosen in regard to work done in previous years).
(2) The Empire generally.
(3) The Great Self-governing Dominions and their place in the Empire—discussion of their form of government.

2nd Term.

(1) The Self-governing Dominions in greater detail.
 (*a*) Canada and Newfoundland
 (*b*) Australia and New Zealand
 (*c*) South Africa
 (*d*) India
 Revise on lines (*a*) to (*f*) (page 517).
(2) The peoples of the Empire—specially emphasising the conditions evolving from the presence of
 (*a*) Colonists and their descendants.
 (*b*) Native populations.

3rd Term.

The Great Highways of the World.

(1) The 'All-Red' Route (C.P.R.—its significance) ;
(2) The Panama Route ;
(3) The Cape Route, and the Cape-to-Cairo Route ;

(4) The Mediterranean Route (*n.b.* proposed Channel Tunnel for overland route to Marseilles);
(5) Trans-Siberian Railway;
(6) Imperial Airways;
taken in detail on following lines:
(*a*) Position—nature—course and extent of route.
(*b*) Times of 'passages,' etc.—advantages and disadvantages.
(*c*) Resources of routes, productions, industries and markets.

II.

Another set of syllabuses was received from a Non-Selective Central School for Girls, situated in Hull. In addition to giving the schemes of work in Geography, History, and Civics, this Head Mistress has tabulated the items in her own schemes which correspond to those given in the *Informative Content of Education* for Group C.

The schemes are reproduced in the following pages.

HISTORY.

Form 1.

1. Primitive Man—stages of advancing culture.
2. Mediterranean Civilisation in outline—influence of Mesopotamia.
3. Early Empires: Persian, Greek, Roman—Britain comes into History as a Roman province.
4. 'Barbarian' attacks upon and settlements within the Roman Empire.
5. Spread of Christianity within the Roman Empire.
6. The Franks and their Empire.
7. Beginnings of the Feudal System.

Form 2.

1. Life in the Middle Ages:
   Feudal System. Chivalry. Pilgrimages.
   Growth of cities:
   Trade. Guilds. Fairs.
   Religion—common all over Europe—unifying influence—a great factor in everyday life.
   (*a*) Monasteries. (*b*) Churches. (*c*) Schools.
2. Beginning of Renaissance:
   Art. Literature. Religious Reform.

Form 3.

1. Renaissance:
   (*a*) Scientific discoveries.
   (*b*) Geographical.
   (*c*) Some political effects of Reformation:
   (i) Break-up of Spanish power.
   (ii) Rise of French power.
2. Colonial Rivalries in America.
3. Industrial Revolution in England.
   (*a*) Agricultural changes.
   (*b*) Manufacturing developments.
   (*c*) Transport.

Form 4.

Great social reforms arising from conditions created by Industrial Revolution:
a. Factory Regulations.
b. Associations of Workers.

c. Publicly provided Education.
d. Poor Law Reforms.
e. Public Health Service.
f. Extension of Franchise.

In October this class carries out a mock municipal election after two or three lessons explanatory of procedure.

Characters appointed to absorb the whole Form :

Candidates	at least two.
Candidates' Agents	one each.
Chairmen of Meetings	one each.
Supporters of Candidates	two each at least.
Stewards, Polling Clerks, Counters, Printers	as required.

Brief accounts of work done are written out by each type of worker.

Form 4 (1938–39). *Modifications due to wireless course being taken : 'History in the Making.'*

1. Local Government.
2. Municipal Matters.
   (*a*) Election.
   (*b*) Council Meeting.
   (*c*) Committees :
      (i) Housing.
      (ii) Town Planning.
3. Wireless Lessons :

September to December.

a. Czecho-slovakia.
b. How to make Peace.
c. The World's Wheat Crop.
d. Holidays with Pay.
e. How far should we welcome Refugees ?
f. Local Government.
g. How Parliament Works.
h. Joint Stock Enterprise.
i. Buying and Selling in Africa.
j. History of Jews in Europe.
k. Raw Materials.

January to March.

a. The Highlands of Scotland.
b. Crime.
c. Roads and Railways.
d. National Service.
e. The I.R.A. Bomb Outrages.
f. The Mediterranean.
g. Election of the Pope.
h. Peopling the Empire.
i. The Real Frenchman.
j. The Budget.

4. Public Health.
5. Poor Law.

Form 4—Civics Course.

Introductory.

History introductory to the course covers general reforms of the 19th Century arising out of the industrial revolution :

(i) *The Poor Law.*
   a. Act of 1601.
   b. Act of 1662.
   c. Speenhamland Decision, 1795.
   d. Act of 1834.
   e. Local Government Act of 1929.
   Growth of Poor Law Movement as far as present-day Public Assistance Committees.

(ii) *National Insurance.*
- *a.* Persons and groups affected.
- *b.* Three types of benefit.
- *c.* Conditions.
- *d.* Differences between Public Assistance and National Insurance.
- *e.* Benefit for adolescents—credit or contributions for those who remain at school to 15 plus.

(iii) *Local Government Reform.*
- *a.* Municipal Corporations Reform Act, 1835.
- *b.* Acts of 1888 and 1894 creating County Councils and Urban District Councils.
- *c.* Development of Towns and their governments in 19th and 20th Centuries.

1. *Local Government.*
   - (*a*) Central (Parliamentary Government). Differences.
   - (*b*) Variety of Local Councils—duties—constitution :
     - (i) County Council
     - (ii) Urban District
     - (iii) Rural District
     - (iv) Borough

     East Riding to provide illustrations.

     Hull considered as typical Town Council, but note that it is a County Borough.
   - (*c*) Election of members of a corporation.
2. *Municipal Election.*
   - (*a*) The Whole Form to ' man ' and carry out an election—Meetings to be advertised and held. Election by ballot on November 1st—the whole school to vote.
   - (*b*) Election and investiture of Lord Mayor.
3. *First Council Meeting.*
   - (*a*) Investiture of Lord Mayor.
   - (*b*) Division into Committees :
     - (i) Elected members (and aldermen).
     - (ii) Co-opted members.
4. *Committees formed.*
   Education. Transport. Health.
   1938–39 Housing and Town Planning.
   Public Amenities.
   Cleansing and Sanitary.
5. *General Plan for Committee Work.*
   - (*a*) Discussion of and notes upon duties.
   - (*b*) Election of Chairman, and Secretary to keep Minutes.
   - (*c*) Selection of topics for discussion—taken from current events.
   - (*d*) Formation of Sub-Committees if desired.
   - (*e*) Formulation of resolution for City Council.
     - (i) General discussion all round subject.
     - (ii) Analysis of points and concentration on one or two of the most important (at this point less desultory talking allowed).
     - (iii) Formal moving and seconding a resolution.
     - (iv) Discussion and vote.
6. Report to Town Clerk resolutions passed (this is instead of circulating minutes for City Council). These are discussed at next Council.

7. Brief history of each Committee to link this section of the work with the development of local government.

GEOGRAPHY.

General Plan of Treatment of Regions :

(1) Surface configuration and river basins.
(2) Climate—regular revision of determining conditions—prevailing winds.
(3) Productions determining distribution of occupations and industries.
  (*a*) Agricultural.
  (*b*) Mining.
  (*c*) Manufacturing.
(4) Commercial highways :
  (*a*) Great distributing centres.
  (*b*) Natural Highways.
  (*c*) Artificial Highways.

COMPARISON OF THE FOREGOING SCHEMES IN HISTORY AND GEOGRAPHY FROM A HULL CENTRAL SCHOOL (A) WITH THE SUGGESTED *Informative Content of Education* (B).

(A)		(B)
	History.	
Form 2.	Life in Middle Ages.	
	Crusades.	Rise of Ottoman Empire.
	Beginning of Renaissance.	
Form 3.	Some political effects of Reformation.	
	Break-up of Spanish Power.	Rise and fall of Spanish Power.
Form 1.	Break-up of Roman Republic.	
	Break-up of Roman Empire.	
Form 2.	Middle Ages.	Increasing importance of economic changes in history.
	Trade, Guilds, Leagues.	
	Discovery of new trade routes.	
Form 3.	Industrial Revolution.	
N.B.—The above are examples when such changes are discussed, but the study of social history involves throughout the study of economic changes.		
Form 1.	Mediterranean civilisation.	
	Movement by sea, canal, road.	Communications and
Form 2.	Growth of cities.	Trade.
	Trade, Gilds, Hanseatic League.	
Form 3.	Renaissance.	
	Geographical discoveries.	
	Colonial rivalries in N. America.	
	Industrial Revolution.	Innovations in production and trade.
Form 1.	Primitive Man :	
	Age of World.	General ideas of relation of oneself to universe.
	Appearance of Man on the Earth.	
Form 3.	Renaissance ; Scientific discoveries.	
Form 1.	Early Empires—Greek and Roman Myths.	Primary propositions of chief religious and philosophical interpretations of the world.
Form 3.	Reformation.	

Forms V and IV listen to broadcast lessons—*History in the Making*—which refer to many points mentioned in Mr. Wells' scheme.

(A)	(B)
Geography. Whole world studied during school course, but not time for an explicit and detailed study. *Form* 1. The Earth—as planet—world climate and vegetation—types of people. Africa and Australia. *Form* 2. The Americas. Principles governing climate. *Form* 3. Europe and Asia. *Form* 4. British Isles. Local Geography. *Form* 5. Economic Geography ; world trade.	Detailed and explicit acquaintance with world geography, with different types of population in the world and the developed and undeveloped resources of the Globe.
Only studied on broadcast outlines. Usually occurs in syllabus as follows : *Form* 1. Earth as a planet. *Forms* 1, 2, 3, 4. Mountain building, ancient and more recent mountains, work of ice. *Form* 4. Formation of coal, some land forms of British Isles, types of soil and effect on agriculture.	Geology of the world.
This year *Forms* 5, 3 and 1 have had wireless talks on the relations between Man and Nature. These have been fitted in with present syllabus, and the uneconomic use of resources, etc., has been amplified in lessons dealing with regions studied in the separate Forms.	Devastation of World's forests, replacement of pasture by sand deserts through haphazard cultivation, waste and exhaustion of natural resources, coal, petrol, water, etc.

III.

In replying to last year's inquiry the head master of a Lowestoft Selective Central School, after indicating the sections of the suggested scheme which were taken in his own school, stated :

> ' It is perhaps fair to say that most of the remaining parts might be " advantageously included." Some of the phrases are rather staggering for a school curriculum, but they probably mean much less than they appear to mean.'

In forwarding copies of his schemes this year, he wrote :

> ' It would be too much to say that we do all that Mr. Wells thinks should be done, but I think that much of the work we are trying to do does square, in spirit at any rate, with many of the Wellsian suggestions.'

An examination of the information of the work in this school which he has supplied gives evidence of this fact.

This school has a full four years' course, and the pupils normally remain in attendance until at least the age of 15. Attention should, we think, be specially directed to the fourth-year course in History in which is included ' elementary economics—money, wealth, capital, banking and currency, labour, trade, etc.'

The syllabuses for Geography and History for the school are reproduced in the following pages.

History.

The Course.

In four years a complete chronological survey of the progress towards civilisation of the leading peoples of the world. From the beginning of the Christian Era,

attention is concentrated on the history of the British Isles, with due consideration given to those events abroad which influence affairs at home.

Aim.

To present an ordered and comprehensible account of this history. To encourage an appreciation of the value of the experiences of people of the past, and a power to analyse, reason, and compare. To demonstrate the essentials of citizenship, together with the order and meaning of elementary economic factors.

Method.

Teaching : study of each period to be

(*a*) political—dates, events, rulers, wars, legislation.
(*b*) social—housing, foods, clothes, working conditions, leisure hours, beliefs, etc., etc.
(*c*) economic—problems and conditions of government, money values, wages, trade, education, religion, etc.

By the Pupils :

In addition to work arranged by teacher, pupils to be encouraged and advised in private work such as

(1) Essays—lengthy, with largely own choice of subject, etc.
(2) Practical—construction of models, diagrams, drawings, paintings, dresses (speeches, also, to be given to class).
(3) Drawings largely suggested by teacher ; e.g. architectural series.
(4) Collections (and management of), foreign coins and stamps.
(5) Use of library—quite unlimited ; teacher's guidance ; ticketing system run by librarians.
(6) Discussion groups ; Project groups.
(7) Excursions to places of historical interest.
(8) Posting of pictures, newspaper cuttings, etc., by pupils.
(9) Attendance for special film displays, slide shows, etc.

History Course.

Year One.

From the Stone Age to the Norman Conquest.

(Egypt, Tigris and Euphrates Valleys, Persia, Palestine, Greece, Crete, Rome, Barbarians, Mohammed, Buddha, Britain.)

(Books : Marten & Carter, I ; Social Life, I ; Illustrated Books.)

Year Two.

The Norman Conquest to the Tudors.

(Special attention to Church power, architecture, guilds, work and wages, the plays, language changes, education, and printing, medicine, beliefs, housing, dress, food.)

(Books : Marten & Carter, II ; Social Life, I ; Source Books ; Illustrated Books.)

Year Three.

The Tudors to about 1789.

(Especially Reformation, Renaissance, Poor Laws, Agrarian and Industrial Revolutions, party politics, punishment and prisons, and all social factors.)

(Books : Marten & Carter, III ; Social Life, II ; Source Books ; Illustrated Books.)

Year Four.

Nineteenth and Twentieth Centuries. Taken as a whole, and in parts such as :

(1) History of Education ; of reforms in factories, and parliament ; of Trade Unionism and Co-operative movements ; of the Irish question ; of the remaking of Europe ; of colonial affairs and administration ; etc.

(2) Outline histories of prisons, shipping, telegraphs and telephones, conveyances, medicine, etc., etc. (complete surveys).

(3) Elementary economics—money, wealth, capital, banking and currency, labour, trade, etc.

(4) British Constitutional Method—local and central government systems ; voting, census taking ; taxation ; etc.

(5) Present-day affairs by wireless, and by discussions.

Geography.

General.

Introductory lessons for all classes are devoted to :—

The World as a sphere ;
Shape of the Globe ; Size, etc. ;
Latitude and Longitude ;
Climate, Zones, and Seasons ;
World Position, Climate and
Vegetation regions, relationships ;

with increasing detail and explanations from 1st- to 4th-year work ; such lessons to be largely revisionary and with particular reference to the Regional Study of each year.

First Year.

Regions of the World.

In the study of the Regions of the World, particular emphasis is placed upon :

(*a*) Form of life, occupations, homes, clothes, as controlled by geographical environment (soils, climate, and vegetation, etc.).

(*b*) The close relationships (racial, trade, etc.) and dependence of the Homeland upon the other Regions of the World.

(*c*) The development of the Human Race through the various stages of hunter, pastoralist, agriculturalist to industrialist, as illustrated by the study of the various forms of life, throughout the Regions of the World.

Second Year.

The British Isles.

Introductory lessons devoted to position of the British Isles with respect to :

(*a*) The World ;

(*b*) The continent of Europe, together with physical and historical connections thereto.

Throughout the year's work particular emphasis to be laid upon :

(*a*) Comparative geography, i.e. the lives of the inhabitants of other parts of the British Isles as compared with our own, with reference to causes for such differences and contrasts.

(*b*) The relation between the various Human Regions and other parts of the Empire and the World :

e.g. Our dependence on imported food supplies and raw materials, and exports of manufactured articles.

(*c*) The varied scenery of the British Isles as related to rock structure, together with types of houses and buildings as controlled by the available building material (based on pictures in Railway Holiday Guides).

Third Year.

The Atlantic Hemisphere.

(a) *Girls' Classes :* In the study of the vegetation regions the topics are closely related with the Natural Science lessons.

Particular emphasis is placed upon the peoples—both native and immigrant—of the regions to be studied in relation to clothing, customs and habits.

(b) *Boys' Classes :* In the study of climate regions the topics are correlated with the Science lessons.

Particular emphasis is placed upon Rock Structure and Relief in relation to vegetation and crop production.

Diagrammatic sketch maps, which stress relationship between Distribution of Population and Occupations in relation to Climate and Vegetation, are introduced at this stage.

The spread and influence of European civilisation into and throughout other regions of the world are considered in relation to the development of agricultural and pastoral regions of Africa and the Americas as complementary to industrial Europe.

This year's work provided opportunity also for the following topics to be touched upon as the occasion arises :

(1) Historical development and exploration of the British Empire. (Continued also in the 4th-year work in the study of Asia and Australasia.)
(2) Great land, sea and air routes as links between the Homeland and the continents of the Atlantic Hemisphere.

Fourth Year.

Euro-Asia.

In the study of *Asia* particular reference will be made to the contrasts between Eastern and Western civilisations as related to geographical environment and racial differences. Emphasis will also be placed upon the Changing East in relation to the influences of Western civilisation upon India, China and Japan, and such topics as the following will be discussed :

(*a*) The Indian Empire and Dominion status.
(*b*) The Yellow Peril both as a population and a trade question.
(*c*) Japan as the Britain of the East.
(*d*) Japan *versus* America in the Pacific.
(*e*) Irrigation in relation to agriculture in India.

Australasia to be largely treated as a region of the world passing rapidly through all stages of human development, from pastoral through agricultural to the industrial.

Special topics to be considered :

(1) Imperial Preference in Trade and Defence ;
(2) New Zealand as the Britain of the South ;
(3) Imperial Airways Development ;
(4) Discovery and Exploration of Australasia ;
(5) Fruit Regions of Australia in relation to S.W. Africa, the Mediterranean lands and Home Trade ;
(6) Native Populations of Australia and New Zealand—Coral and Earthquakes and Volcanoes.

Europe : The study of the geography of the countries of Europe will be largely considered in its relation to :

(*a*) Trade with the United Kingdom and the neighbouring countries ;
(*b*) Tendencies towards the development of nationalities based on language and race ;
(*c*) Industrialisation based on the development of hydro-electric power or co-operative farming (as in Denmark) as a means to economic independence ;
(*d*) Varied post-war political and economic experiments ;
(*e*) The League of Nations and its economic work.

Revision of the *British Isles* in its world setting, with particular reference to post-war changes of—

(*a*) Overseas and home trade ;
(*b*) Industries and Electric Power ;
(*c*) Distribution of Industries and new developments.

Local Geography.

Throughout the four years' course, *Local Geography* will be introduced into each year's work whenever the topic under discussion can be related to local geographical conditions.

Map-work.

Mapping of positions of school, home, landmarks, etc., as related to relief based on actual knowledge of

(*a*) direction of main roads ;
(*b*) higher positions and low-lying regions of the locality ;
(*c*) coastal cliffs and beaches.

Localisation of industries as related to road, railway and river transport, harbour facilities and relation to fishing grounds of the North Sea.

Mapping of sea roads as related to distribution of sandbanks. (See Nautical Almanac and Coastal Charts.)

Study based upon :

(*a*) Papier-mâché Contour Map of Lowestoft—Industries.
Constructed by Form VI Boys, April 1934.
(*b*) Ordnance Survey Maps (Geological and Land Utilisation).

First Year.

Regions of the World.

The following topics will be considered with particular reference to either the Lowestoft Region or East Anglia as a whole :

(1) Wheatlands of the World as compared with the Wheatlands of Eastern England—intensive farming and crop rotation—agricultural villages and market towns as compared with the Prairies and Pampas, with collecting and exporting centres.

(2) Sugar production—Sugar-cane of tropical regions as compared with Sugar Beet of Temperate Regions (Norfolk—Cantley factory).

(3) Cattle Ranching of Pampas as compared with stock-raising on the marsh lands of the Fens and Suffolk and the Dairy Farming of Essex and lowlands of the West.

(4) The North Sea and Fishing with particular reference to :

(*a*) Lowestoft Trawling Industry.
(*b*) The East Anglian Herring Fishery.
(*c*) Pickling and Curing Trades.
(*d*) Fish-canning Industry (C.W.S. Factory).

Relation between the Fishing Industry and British Shipping, Naval Power, Trade Routes and the Empire.

In the study of all Regions of the World, emphasis to be placed on comparisons and contrasts with the Home Region wherever possible.

Second Year.

The British Isles.

This year's work will allow for a more detailed study of Lowestoft and Region along the following lines :

(*a*) The Fishing Industry—as in the last year's work—together with further study of habits of fish, methods of curing, and home and export trade. (Klondyking.)

(*b*) The East Coast Holiday Resorts (Drier side of England) compared with other Holiday Regions (Lake District, North Wales, South Coast, etc.). Climate *versus* Scenic Attractions in relation to Rock Structure.

(*c*) Lowestoft as a Trade Port—Timber, coal imports, etc.

(*d*) Lowestoft as an industrial centre—Canning, Ice, Marine motors and Shipbuilding.

(*e*) Coast Formation in relation to rock structure, with particular reference to Coastal Erosion and the Coastal Defences (as devised by the Borough Surveyor).

(*f*) Lowestoft's water and electric power supplies.

(*g*) Lowestoft and the Broads.

Third Year.

Throughout the year's work, reference to, and comparison with, the Lowestoft Region will be made wherever possible ; e.g. :

(*a*) Beach formations and sand-dunes (work of sea and wind) compared with the sand of the deserts.

(*b*) Wheat and crops rotation compared with wheat farming on the Prairies of Canada.

(*c*) Fishing industry compared with

(i) Cod Fisheries of Newfoundland ;

(ii) Salmon Fisheries of British Columbia ; etc.

Fourth and Fifth Years.

The topics given under 'Second Year' will also be taken during the 4th and 5th years' work, forming the basis of individual research work in the preparation of Essays dealing with the geography of the Lowestoft Region.

Supplementary Geography.

The Geography lessons will be supplemented whenever possible by :

(1) The Daily Press and Newspaper Supplements (*The Times* and *Telegraph*). *The Times Trade and Engineering Supplement.*

(2) *The Geographical Magazine.*

(3) The B.B.C. Geography Lessons (when time-table permits).

(4) Film Displays (35 mm.). Films borrowed from the G.P.O. Film Library. (Evening Displays—voluntary attendance.)

(5) Epidiascope displays using holiday snaps and picture postcards or pictures collected by the pupils. (Holiday Guides.)

(6) *Group and Project Work : 1st and 2nd Years :*

The classes will be divided into groups to be engaged in the compiling of Pictorial Maps to illustrate geographical distributions, e.g. the Peoples and Occupations, the Scenery, the Crops, the Animals, etc., of the region under study.

Group and Project Work : 3rd Year :

The construction of Flow-Charts for various industries based on the year's regional study : e.g. :

The Cotton Industry ;	Rubber Production ;
The Manufacture of Paper ;	The Herring Industry ;
The Manufacture of Soap ;	etc.

The work to be done largely in the form of maps, illustrations, and sectional diagrams with a minimum of writing. Each boy to give a short talk on his own section of the chart. Details of industries to be obtained (if possible) direct from the manufacturers.

Group and Project Work : 4th Year :

Essay on the Lowestoft Region to be compiled with the aid of maps, graphs of statistics (trade, passenger traffic, etc.), based on the East Suffolk Regional Development Plan, and Model Relief Map of Lowestoft constructed by Form VIB, April 1934.

IV. Modern Language Teaching.

In the preceding inquiry there was no reference to the contribution which may be made by Modern Language Teaching to the Informative Content of Education. A member of the Committee has pointed out that 'modern methods of Modern Language teaching, conceiving their subject as essentially *living* and a medium of *people*, have a considerable informative contribution which is not necessarily accounted for under other headings.' Since a second language is often begun at about the age of 11 plus, some reference should perhaps be made to this contribution.

In the classroom where modern language is taught, a good first-year course includes familiarisation with the following facts about France and the French :

Frontiers ; Four chief rivers ; Seven chief towns ; Two chief mountain ranges ; Colonies.
Agriculture : Wheat and Vines.
Industries : Silk ; Iron and Steel ; luxury goods.
Money.
Paris : more details.
System of government.
National Fête ; National Anthem.
Departments and Provinces.
Diet.
Family life.
The story of Joan of Arc.

In the following years similar treatment is extended to cover *education ; customs ; sports ; methods of transport ; outstanding personalities in literature, art and science.* The treatment of these details is very simple and elementary, but this amount of information is definitely learnt by many who begin a foreign language at 11 plus. The three stages (to continue with reference to French alone) provided by the B.B.C. under the headings 'Early Stages in French,' 'Intermediate French,' and 'French for VIth Forms,' strongly support this aspect of the teaching in their weekly lesson, which also includes songs and games. 'Early Stages' are taken regularly by 1,135 schools, 'Intermediate French' by 565, and the senior course by 710. The Early Stages in German are taken by 348, and German for Vth and VIth Forms by 453 schools.

Outside the classroom good Modern Language teaching includes a many-sided Modern Language Society which will arrange, among other things, for visits to

cinemas, theatres and art galleries. The Modern Language Association has 1,250 slides of French life, which are lent to schools for use by such societies, which also sometimes arrange conferences to show the working of bodies such as the International Labour Organisation. Correspondence between individuals or between classes or between whole schools, international exchanges, school journeys and international camps, all of which are usually organised in connection with language teaching, contribute to the informative content of education.

V. General Observations on Senior School Schemes.

The Committee would have preferred to have had before them a larger number of schemes and to have been able to make a more detailed comparison. This, however, was found impossible. The syllabuses reproduced in the foregoing pages are therefore presented as specimens which have been submitted by head teachers who had previously given evidence of interest in the Committee's inquiry. The Committee would also have preferred to have schemes of work giving evidence of opportunities afforded to the same pupils by successive junior and senior courses. Unfortunately these were not available, and the schemes for senior schools had therefore to be considered quite separately.

These syllabuses, however, do provide sufficient material to illustrate the methods of approach to the subjects and to indicate the wide scope of the work attempted. Regarding both of these features of the schemes there will certainly be differences of opinion. Severe adverse criticism of the geographical syllabuses has for example been expressed by a University Lecturer in Methods of Geography Teaching. 'In Geography,' he said, 'the method is *not* to work from cause to effect. Much Geography can be understood without reasons (in the scientific sense).' He objected to references to 'World fundamental principles.' 'To begin with these,' in his opinion, 'is all wrong. World principles surely come at the end of the course. Thus all syllabuses which want to start with geography principles are useless.' In passing he expressed objection to a statement from the Spens Committee Report wherein the idea of 'well-grounded principles' is mentioned.

The Spens Committee, however, were concerned with the curriculum of secondary schools ; and the pupils in these schools, like those for whom the schemes under consideration were formulated, have already been in school at least five years. During that period some geography will have been taken, and the question arises whether all courses, regardless of the age of the pupils for whom they are planned, should start from the same point or whether those responsible for syllabuses should have regard to instruction and training previously given.

In the opinion of this critic, 'the idea of geography is wrong in much of this Report. There aren't,' he adds, 'any geographic "forces" compelling human beings. At the best the physical phenomena only *influence* men over a wide range of possible choices of occupation.' This, of course, raises the old question as to the interaction between environment and personality. But it would be interesting to know whether this critic would admit that man may be so strongly influenced as to be compelled to take certain lines of action in order to use his environment most advantageously. Why, for example, are some Eskimo nomads ?

Other critics focussed attention upon the prominent place given to, and the time obviously occupied by, the study of Britain and the British Commonwealth. Again the likelihood of divergencies of opinion will be apparent, whether the subject under discussion be Geography or History.

The Committee decided, therefore, not to concern themselves unduly with criticism of details, but to offer the following general observations.

Whether the subject studied be Geography or History—and in passing it should be noted that these subjects cannot be adequately studied if they are presented in

isolation or if they are taught as wholly separate and distinct branches of knowledge—the proper presentation of the facts concerning the place and importance of Britain and the British Commonwealth requires that these be seen in right perspective both in relation to time and space. They cannot thus be portrayed without bringing in the outside world and without due regard being paid to the march of time. These facts have received a measure of recognition during recent years. (For example, much more can be taught of Russia in State schools to-day without arousing opposition in certain quarters than could have been attempted even twelve months ago.) But as yet they have not been allowed to exercise sufficient influence in the formulation of schemes of instruction. By focussing attention upon the needs created by a recognition of these facts, and by suggesting modifications in the scope of the syllabuses of instruction and in the emphasis to be given to various sections of subjects taught, Mr. Wells rendered a useful service to the general public, and especially to teachers and other educationists.

But to discern these needs, however clearly, is not enough. Even to stimulate a strong desire to satisfy them may not be sufficient, unless steps are taken to gratify the demand of teachers for facilities to obtain new information and for opportunities to integrate their knowledge. Teachers in active service are perhaps more conscious than anyone else of their difficulties in these directions. When they are compelled, as they are, to engage in actual teaching for five and a half hours each day—for even in the best-staffed of these schools free periods are few, and in many they are quite unknown—and when in addition they have to spend time each evening in marking written exercises, the opportunities for gaining new knowledge cannot but be inadequate. With the rapid growth of knowledge the need for the teacher to continue to be well informed is of the utmost importance if he is to be saved from becoming a ' retarding shadow ' upon the youth of the country. Teachers are fully conscious of this fact. Many of them, despite the handicaps imposed by the conditions of their service, endeavour to gain up-to-date information and to take an active and intelligent interest in what is happening in the world ; their attendance at Refresher Courses in thousands each year is evidence of this fact. Some of them devote to this task so large a proportion of their leisure time that they run a risk of segregating themselves from other members of the community and becoming a class apart. Such a possibility cannot be contemplated with equanimity, since it constitutes a threat to them as teachers and citizens at least as dangerous as out-of-date equipment in the sphere of knowledge does to their professional efficiency. Much more should, therefore, be done to afford facilities for teachers to gain up-to-date information and for them to integrate the whole of their knowledge so that it can be used to interpret everyday events and to discover purpose.

Something is already attempted in this direction for teachers in State schools. Limited opportunities are available for attendance at certain types of Refresher Courses arranged by the Board of Education, and associations of teachers are organising for their members similar facilities, though of shorter duration, with increasing frequency. But much more is urgently necessary. The opportunity for teachers to obtain what may be described as ' daily sustenance ' should be regarded as an essential condition of the teaching service. Time for this should be afforded, and the beneficial employment of that time should become a part of the ordinary routine of professional life.

But even this will not be enough. At regular intervals there should be afforded adequate Refresher Courses of longer duration. The ' Sabbatical Year ' for every teacher should be regarded not as an impracticable ideal but as a first necessity if teachers are efficiently to perform their duties and to remain alive and alert throughout their careers. But this implies the organisation of courses on modern lines, in respect to which something more may be necessary as part of the normal training of teachers. Both Elementary and Secondary schools will inevitably lag

somewhat behind the Universities. Whether trained in Training Colleges, where the staff are University graduates, or at Universities themselves, the initial equipment of teachers will be largely determined by the instruction afforded by the professors and tutors and the attitude adopted by them to new knowledge. If, therefore, in the Universities there is a time-lag, that lag will be intensified in the schools. This aspect of teacher-training merits more consideration than appears to have been given to it hitherto. It certainly gives emphasis to the need for Refresher Courses.

But possibly a further observation should be offered in relation to these. They should be real Refresher Courses and not merely gatherings at which tired tutors are expected to deliver at the end of term lectures, in more or less modified form, which have been prepared for other occasions. They must be times of refreshment, not simply a series of meetings for listeners. They will necessarily afford opportunities to acquire new facts, but, whether these be few or many, the course will not serve its true purpose if the acquisition of facts be the only result. A Refresher Course of the type envisaged will do much more : it will assist the teacher to acquire a sense of purpose and validity and enable him to see his work against the background of the changing world. He will then be able on return to school to assist his pupils to become broadminded, helpful, generous-spirited, capable, and, as far as circumstances of the school allow, technically equipped.

SECONDARY SCHOOLS.

The Committee had before them the relevant sections of the Spens Committee's Report on the Curriculum of Secondary Schools and gave some consideration thereto. They were of the opinion, however, that this aspect of their inquiry demanded much more information and would require far more time than was available this year. They therefore decided to ask to be allowed to continue the work during the coming year. If this request is granted it will be possible to study in greater detail both the conclusions of the Spens Committee and the informative content of the curricula at present in use in secondary schools.

RESEARCH IN EDUCATION

REPORT of the COMMITTEE appointed to consider and report on the possibilities of organising and developing research in education (Prof. F. Clarke, Chairman ; Mr. A. Gray Jones, Secretary ; Miss D. Bailey, Mr. J. Compton, Dr. Evan Davies, Mr. E. Salter Davies, Dr. S. Gurney-Dixon, Dr. M. M. Lewis, Sir Richard Livingstone, Mr. P. B. H. Lyon, Prof. R. A. C. Oliver, Mr. C. A. Richardson,[1] Mr. W. H. Robinson, Mr. N. F. Sheppard).

CONTENTS.

1. Introduction.

The Committee was appointed by the Council of the British Association at the request of Section L (Educational Science) in view of the special interest taken by

[1] Mr. C. A. Richardson attended on behalf of the Board of Education but did not vote in the proceedings nor is he a signatory to the report.

the Section in the general question of educational research in this country. The terms of reference are explicit; they empower the Committee to enquire into the possibilities of organising and developing educational research. The Committee was neither requested to initiate such research nor to examine critically the quality of such research as has been or is being undertaken. Accordingly the Committee's work involved two stages.

(*a*) It was necessary first to survey briefly the nature and extent of educational research in England and Wales;

(*b*) When this survey had been completed the Committee proceeded to consider proposals for such further organisation and development of educational research as seemed in their view to be both practicable and desirable.

The meaning of the term 'educational research.'—The Committee have throughout used the term 'educational research' in its widest sense. They hold that it should not be confined to highly specialised academic studies such as are not always capable of application in the classroom or in a wider professional field. It should include not only formal investigations such as inquiries into examinations, intelligence tests and studies of mental factors, but also experiments and inquiries about such matters as the curriculum and organisation of schools, and their equipment.

On the other hand there is a limit to the width of this definition. True research involves careful systematic and thorough investigation with a view to ascertaining objectively the answer to a question or questions that have sufficient intrinsic importance to warrant investigation. This is the limiting criterion that the Committee have applied.

2. A Brief Historical Sketch.

A survey of the amount of educational research completed or proceeding in England and Wales reveals the fact that such research as has been conducted has been neither adequately registered nor effectively co-ordinated. Its results have generally not been made available in such form as to influence readily administrators, teachers, and the public. Moreover, there are large and important areas of investigation that still remain to be explored.

The need has long been felt for some organisation to co-ordinate and stimulate research and to direct inquiries into new developments of education. Such organisations already exist in America (e.g. the International Institute of Teachers College, Columbia University); there is an International Bureau of Education at Geneva and there are Educational Research Councils in Scotland, South Africa, Australia, New Zealand and Canada.

In this country attempts have been made in recent years to found similar bodies. The British Psychological Society established in 1922 a *Committee of Educational Research*. That scheme proposed a small executive committee in London with a secretary, together with a larger advisory body comprising Professors of Education and of Psychology in British Universities, together with other persons qualified to assist in educational research. The Committee's function was not to prosecute research but to register, co-ordinate, facilitate co-operation, to guide young workers and to foster desirable inquiries. Although the Committee published accounts of work in progress, the scheme did not come to fruition and the Committee ceased to function in 1935.

Its duties were then taken over by the Education Section of the British Psychological Society and the latter's Committee on Human Mental Measurements. The British Journal of Education Psychology continues to record summaries of research into mental abilities, including published and unpublished theses submitted for higher degrees.

The Workers Educational Association attempted in 1928 to found a *Bureau of*

Educational Research and Information whose services would be available to the W.E.A. and to subscribing bodies, but the financial difficulties proved insuperable.

In 1933 the Royal Society of Teachers (formerly the Teachers Registration Council) convened a series of conferences with a view to setting up an organisation independent of the Society which would organise and develop research. A Committee was formed representative of the Universities and teachers' associations to establish a suitable organisation, and the *Educational Research Council* was formally established in 1935. Its aim was defined as follows :—

> ' to encourage and foster research in all branches of education and to co-ordinate the collection and publication of results.'

Difficulties of finance and organisation terminated the existence of the Council in June 1937 before it had been able to attempt any effective work.

The present Committee was sanctioned by the General Committee of the British Association in November 1938 and held its first meeting on February 9, 1939. Six meetings have been held.

3. The Present Position of Educational Research in England and Wales.

The Committee were impressed at the outset by the fact that no adequate survey had yet been made of the extent and nature of educational research and inquiry in this country.

As a preliminary it was resolved to address a suitably worded questionnaire [2] to the following :—

1. Local Education Authorities ;
2. University Education Departments and Teachers' Training Colleges ;
3. Educational Societies and organisations :
4. Teachers' Associations.

In addition information was sought from the Board of Education,[3] and from individual workers who have engaged in research.

The Committee recognise that an elaborate and detailed survey was not possible in the time available and without the services of a full-time investigator. Nevertheless they are satisfied that the information procured has proved adequate for the immediate purpose and has enabled them, through the willing co-operation of the above-mentioned bodies, to complete a survey which they believe to be more comprehensive than any which has been hitherto attempted in this country.

(i) The Local Education Authorities.

The questionnaire was sent to each of the 315 Local Education Authorities in England and Wales. Replies were received from 120 (26 counties, 36 county boroughs, 58 boroughs and urban districts (Part III, L.E.A.'s)).

The reply was a *nil* return in 81 cases (16 counties, 19 county boroughs, 46 Part III). The remainder (10 counties, 17 county boroughs and 12 Part III) fairly represents the minimum number of authorities under whose auspices some form of educational research or inquiry of wider rather than local interest has been conducted in recent years. But 39 out of 315 is a notably small minority. If it is asked why the figure is not larger, one explanation is that many of the 170 Part III Authorities are too small to undertake anything beyond routine work. Again, in the case of the larger

[2] See Appendix.

[3] Whose interest in the Committee's work was shewn by their appointment of Mr. C. A. Richardson, H.M.I., to attend its meetings. The Welsh Department of the Board through their Permanent Secretary and Chief Inspector desired to be kept fully informed of the Committee's proceedings.

authorities, unless the Education Officer is particularly interested in research or inquiry, he is usually too busy to spare the time to encourage or develop it. If he is interested, however busy he may be, he manages somehow to find the time.

Of the 81 *nil* returns, 39 favoured the creation of a national organisation for the more systematic pursuit of research, 3 were doubtful, 38 expressed no opinion.[4] Only 1 was definitely against the proposal (on the grounds that ' the existing machinery seems adequate for the purpose of any inquiry '). One opinion emphatically for a national organisation was to the effect that ' such a body could allocate which objects of research could appropriately be carried out by the local authorities and by the Universities.' A similar opinion stressed the value of such an organisation ' in the pursuit of inquiries into

(*a*) examinations,
(*b*) intelligence tests,
(*c*) the value or otherwise of Special Schools for Mentally Defective Children.'

Of the 39 local authorities reporting some form of research, 10 were counties, 17 county boroughs, and 12 boroughs or urban district councils. An analysis of the returns shews that those from two counties merely reported participation in the Land Utilisation Survey. In 3 boroughs and 1 urban district the inquiries or research were of limited extent (use of leisure, intelligence tests at one school, use of wireless and examining for special place examinations).

In the remaining 33 the inquiries varied considerably in character and extent, but deserve definitely to be regarded as research. The research falls into three main classes :—

(*a*) psychological, including tests of attainment of intelligence and vocational guidance ;
(*b*) educational, e.g. examinations, curriculum, bilingualism,
(*c*) medical, including nutrition.

The research was carried out by the L.E.A. in 21 cases and jointly with other agencies in 12 cases, in 9 of which financial support was given by the authority and in 3 cases by the co-operating organisation.

Of these 39 L.E.A.'s, 25 (7 counties, 11 county boroughs and 7 Part III authorities) favoured the creation of a national organisation for research, 11 (2 counties, 5 boroughs and 4 Part III authorities) expressed no opinion, 2 were doubtful and 1 (a borough) was against the proposal.

General observations.—Considerations of time and space prevent the submission of a full list of the researches or inquiries reported, but a brief specimen list is given below. It would be undesirable to draw any comparisons between L.E.A.'s in respect of the research undertaken. Estimates of its value are not called for here nor could any such estimates be justified without prolonged investigation beforehand. But it may be confidently asserted that in at least some dozen cases the work completed is of such value as to warrant publication outside the Authority's area. One cannot read some of the reports without first paying tribute to the time and energy so effectively and spontaneously expended, and next reflecting on the need for some central body to co-ordinate such research and inquiries, to make their results more widely known, to offer suggestions for further investigations, and to prevent overlapping and the repetition of inquiries already successfully completed. This point cannot be better emphasised than by quoting the reply from a large county borough, whose research (not listed here) is of outstanding quality :—

[4] Nine counties, 7 county boroughs and 23 Part III authorities supported the proposal. Seven counties, 9 county boroughs and 22 Part III authorities expressed no opinion.

'There is need for a " sorting house " where the outcome of researches made by the L.E.A.'s can be assessed with respect to their national value. The outcome of these researches of national importance could then be made known generally. From such a source too there could come suggestions as to the investigations that wait to be carried out.'

Specimens of the inquiries conducted under the auspices of Local Education Authorities.

Counties :

A. The Technique of Vocational Guidance for Juveniles. (In conjunction with N.I.I.P. Financial support from the L.E.A.)

B. An examination of the operation of the Secondary School Entrance Examination for the period 1933–38. (By the L.E.A.)

C. The extent of backwardness or retardation among the children of 10–12 years in public elementary schools in a county area. (In conjunction with N.I.I.P. and a panel of teachers trained in the Binet-Simon tests. Financial support from L.E.A.)

D (*a*) Weight, Height and Nutrition.
(*b*) Dietary Investigation.
(*c*) Dietary and Nutrition.
(*d*) Hearing (Audiometer testing).
(By L.E.A. in co-operation with Ministry of Health, Carnegie U.K. Trust and Revitt Research Institute and Medical Research Council.)

County Boroughs :

E. Selection of skilled Apprentices for Engineering Trade.
The value of Vocational Tests.
(By L.E.A.)

F. (*a*) Enquiries (4) into Standardised Tests and their application.
(*b*) Investigation and Report on the dull backward and maladjusted child.
(By L.E.A.)
(i) In co-operation with Edinburgh University.
(ii) In co-operation with Central Association for Mental Welfare.
(Financial support from L.E.A.)

G. (*a*) The mentality of a cross section of the school population.
(*b*) Heart Disease in Childhood.
(Both without financial support from L.E.A. (*a*) By Burden Mental Research Trust, (*b*) Bristol University.)

H. High temperature radiant heating of schools. By L.E.A. in conjunction with N.I.I.P. The cost was first met by L.E.A. and later by Electrical Development Association and a firm of electrical engineers.

Boroughs and Urban District Councils. Part III Authorities :

I. (*a*) Discipline and freedom.
Transfer examinations.
Skills and activities.
(*b*) Survey of schools with regard to intelligence and schools.
((i) By local branch of N.E.F. ; (ii) by the L.E.A.'s psychologists.)

J. (*a*) A sickness absence survey.
(*b*) An experiment in nutrition.
(*c*) Effects of temperature and ventilation on mental output and fatigue.
(*d*) Artificial lighting.
(L.E.A. in conjunction with N.I.I.P. with financial support in one case.)

K. (*a*) Children's Verse.
(*b*) Survey of school buildings, equipment and furniture.
(*c*) A six months' investigation by an educational psychologist.
(By L.E.A. In (*c*) with help of Central Association for Mental Welfare.)

L. Mental Surveys.
Classification in Senior Schools.
Methods of Selection for Secondary Schools.
Blackboards.
(By L.E.A.)

Note.—This is only a specimen list ; several L.E.A.'s have published valuable reports of inquiries into such matters as, e.g., school broadcasting and vocational guidance.

(ii) Universities and Training Colleges.

(*a*) *University Education Departments*.—The questionnaire was sent to 21 University Education Departments ; replies were received from 10 ; of these, 9 supported the formation of a central organisation for research, 1 expressed no opinion.

As might be expected, there is a considerable amount of research undertaken in connection with the university education departments. It falls into two main divisions :—

(*a*) Research carried on by members of the staff.
(*b*) Research prosecuted by graduates supplicating for higher degrees (e.g. M.A., M.Ed., or Ph.D.).

In three cases lists of published work have been supplied ; in other cases lists are available when required. To list and classify this research here is not practicable, but some general observations can be made as to its variety and extent. Selections from a specimen list are subjoined :—

Research carried out at a Northern University.

1936 *Lady Barn House and the work of W. H. Herford.*
Fabrics and their decoration. Decorated textiles from Yunnan.
The Co-ordination of Law and Administration.
The Educational Film and Modern Studies.
Critical notice of 'An Examination of Examinations.'
The use of Hearing Aids in the Treatment of Defects of Hearing in Children.

1937 *Experiment in Education.*
German Education : a retrospect and reassessment.
Modern Language Teaching on the Decline.
An Enquiry concerning the Practicability of Typical Educational Aims.
The Use of Hearing Aids in Schools for the Deaf.

1938 *An approach to the study of a Foreign Country.*
The Position of Modern Language Teaching.
Tests of Hearing Aids and Lip-reading.
The Handicap of Deafness.

General Observations.—(1) The amount of research undertaken by the staff is obviously governed by the scale on which the department is staffed, and by the time available for original work to be undertaken. Lectures, the supervision of teaching practice and examinations bear more heavily on the available time at a university where staffing is not on a generous basis.

(2) It would appear that the special interests of the head of the department

naturally have some influence on the nature of the research undertaken, e.g. whether it is mainly psychological, historical, or concerned with problems arising out of the curriculum of schools.

(3) The provision in certain universities of specified lectureships or research studentships in some aspect or other of education naturally stimulates research in these cases. Thus, one university offers from time to time an advanced studentship in education of the value of £150–£200, the successful candidate to undertake research and also to enter for the degree of M.Ed. and in addition there is a sub-department in the education of the deaf (staffed by a reader and two lecturers) ; this department has carried out research throughout the last nine years.

(4) The research undertaken by students is carried out during the course of study for a higher degree. (This is not to say that in some cases the research may not be undertaken as an end in itself.) Without a complete list of theses in education presented for higher degrees at all universities and colleges in England and Wales it is impossible to say whether there is overlapping and whether a student may not be devoting time and energy to the study of some subject which has already been fully and satisfactorily investigated elsewhere. The great majority of theses remain unpublished, but an abstract of their content is usually available at the university, and it should again be noted that those dealing with mental abilities are recorded in the *British Journal of Educational Psychology.*

(5) The existence of a research degree in education at certain Universities served to encourage systematic inquiries at those centres.

(6) The amount and extent of university research in education appear on a summary view to be somewhat less than that carried on in other departments (e.g. the sciences, history, languages). This is no doubt largely due to the fact that education as a subject is not generally studied in undergraduate courses and that candidates for research degrees in education are required to have taken a year's post-graduate study in education and in addition, have had experience of teaching before embarking on recognised research.

(*b*) *Training Colleges.*—The questionnaire was issued to 82 colleges and replies were received from 19, of which one was a *nil* return. Of the 19, 9 favoured the proposal for a national committee, 9 expressed no opinion, and 1 was against it.

General Remarks.—The research and inquiries reported are of a minor character and are carried out by members of the staff. Lack of time and financial difficulties are mentioned as obstacles to the prosecution of research and it will be noted that in most of the colleges the students only take a two-year course for the teachers' certificate and that the academic standard falls below that which obtains in the university education departments. As the specimens quoted below will indicate, the inquiries are mainly connected with the curriculum of primary schools and are usually undertaken as much with the object of training the student in independent inquiry as with that of arriving at results that are valuable in themselves.

Among points of interest are the award at one college (domestic science) of a studentship of £75 to a student on the completion of a three-year course for the purpose of carrying out studies under the direction of the Principal. At this college work has been carried out continuously since 1935 'on the application of the principles of good posture to Housecraft.'

At another college, advantage was taken of its removal to new buildings to experiment with a new type of subject room which will be suitable to the subject taught, and flexible in adaptation for lecturing, tutorial methods or laboratory work. A special chair was finally designed for this purpose, has since been patented and is now manufactured by a firm of educational furnishers. The form of equipment adopted was worked out in collaboration with the college staff and the city architect's department. This college has also taken part in the local civic survey.

Specimen list of research carried out at a training college.

Still in progress :—

An investigation into the scientific interests of boys and girls in Senior Elementary Schools, as indicated by the questions they ask in response to direct invitation.

An investigation organised by a Standing Committee of the Geographical Association into children's understanding of contoured maps was carried out in local schools, as well as elsewhere by old students of the College at the suggestion of the lecturer in geography. The results are to be published later (based on this and other data).

(iii) EDUCATIONAL ASSOCIATIONS AND TEACHERS ORGANISATIONS.

(*a*) *Educational Associations.*—The questionnaire was issued to 14 educational associations. 'Subject' associations were excluded, though it is known that some of these have conducted research into methods of teaching individual subjects. All of the associations approached except 1, supplied information. In 7 cases they approved of the principle of a national research committee ; in 3 cases they asked for further information and in 3 they expressed no opinion.

General Observations.—As might be expected, the amount of educational research—in the widest sense of the term—conducted by educational associations is both varied and extensive. It covers such items as the survey of Education for the Blind and inquiries into the assessment of the intelligence of blind children (by the National Institute for the Blind) and the detailed syllabuses in biology and reports on the teaching of General Science (by the Science Masters' Association) as well as the inquiries into various aspects of adult education conducted by the Workers' Educational Association.

Generally speaking, the title of each association indicates the scope of such research and inquiries have been carried out under its ægis. Thus the British Film Institute is concerned with the ways in which the cinema can be used in the service of the community other than as 'entertainment.' Hence it has (*inter alia*) compiled reports on the use of the film for teaching various subjects in the curriculum, and has investigated the effect of the film on the adolescent, and it takes a special interest in the technical requirements of optical aids.

Similarly, the National Institute of Industrial Psychology has conducted inquiries of outstanding value into two aspects of education on which the Institute claims expert knowledge. These are :—

(*a*) The heating, lighting and ventilation of schools ;
(*b*) Vocational guidance for school children.

Again, the Central Association for Mental Welfare is particularly interested in the 'problem' and 'retarded' child, and it is noteworthy that the Association made investigations on this subject in 10 local education areas during 1936 and 1937 at the request of the L.E.A.'s concerned. (The fact that certain of these investigations do not appear to be known outside these areas may be cited as an illustration of the services that could be formed by a central committee or council for disseminating the results of educational research.)

Considerations of time and space prevent a detailed examination here of the nature and extent of the research work of these educational associations, but it is evident that quite apart from what might be called their propagandist work in education several of these associations have conducted pioneer investigations which are of definite value.

The wide range of these inquiries within the special field of the organisation is

notable in the case of the British Institute for Adult Education and the New Education Fellowship. Among the inquiries conducted by the former in recent years, are investigations of reading interests and habits, educational uses of the gramophone, 1933–36, the educational work of the unemployed clubs, the ' consumers ' (i.e. the student's view of adult education, and a survey of art galleries and loan facilities. The New Education Fellowship has recently completed two inquiries, one on examinations and another on the training of teachers and is at present investigating the relation of the independent schools to the state system. Nor should the inquiries conducted by the Central Council for School Broadcasting be overlooked : an excellent example is the report on experiments designed to illustrate the reaction of senior school pupils to broadcast lessons (Inquiry Pamphlet No. 4).

This list could be considerably amplified if one were to cite the systematic inquiries conducted under the ægis of the various educational trusts ; a good example is the Enquiry into Secondary School Libraries, which was initiated in 1936 by the Carnegie United Kingdom Trust, and covered ground that had not previously been explored.

As there are many associations connected with some aspect or other of education and their activities are widespread there is a clear need for some central body which would accumulate information about their activities, more particularly their positive achievements in research. This would in due course imply the critical selection and recognition of unquestionably valuable results of experimental work that had been undertaken in a scientific spirit, as distinct from investigations prompted more by the desire to prove a thesis than to discover truth objectively. This function of impartial analysis is one that can only be performed by a representative central body.

(*b*) *Teachers' Organisations.*—The questionnaire has been issued to all of the principal teachers' Associations (10). Full information has been received in every case. Seven, including the four Associations of Secondary Teachers, and the Head Teachers, have approved of the principle of a national research committee ; in the remaining cases no opinion has yet been expressed.

General Observations.—Teachers' organisations were founded primarily to advance the professional and educational interests of teachers, and it is true to say that the establishment of national salary scales and superannuation schemes, and the improvement of conditions of service (such as security of tenure) inevitably took precedence over other activities. These professional activities will continue to be important, particularly in times of economic stress. In recent years, however, the educational activities have developed considerably and teachers are exercising more influence on the nature of the curriculum, examinations, and teaching methods generally. This is in accordance with their ultimate wish to give the profession as large a measure of self-government as is both reasonable and practicable.

Accordingly most teachers' organisations have from time to time set up committees to explore certain problems and the results of their inquiries have been published in reports or memoranda which are often published through trade channels. Thus, for example, the National Union of Teachers have investigated in collaboration with the Association of Education Committees such questions as the Entrance Examination to Secondary Schools, the ' extra year ' (the influence of the higher school leaving age), School Buildings (in conjunction with the N.I.I.P.), and the Training of Teachers (N.U.T. alone). This side of the Union's work is rapidly expanding ; the published volumes have had a wide circulation, and it is understood that the Union has in contemplation an extended programme of educational inquiry.

Again both the Assistant Masters and the Assistant Mistresses Associations have published memoranda on the teaching of various subjects (e.g. English, History,

Modern Languages, Geography) (by the former) and Classics, French, Physical Education, Religious knowledge (by the latter)). The Assistant Masters have also produced a handbook for School Librarians, and they are now investigating the work of Careers Masters and (in collaboration with the Science Masters Association), the teaching of Science.

The National Union of Women Teachers has also produced a series of booklets on the Infants', Junior and Senior Schools, while the National Association of Schoolmasters has (*inter alia*) completed investigations on the Extra School year, Juvenile delinquency and on School Camps.

Not the least interesting and pertinent contribution, from this Committee's point of view, is that of the National Association of Head Teachers. Its first general Secretary, the late Mr. T. G. Tibbey had always advocated the need for research in education, and as a memorial to him the N.A.H.T. have endowed an annual lecture on some aspect of educational research. Three such lectures have already been given.

Periodically, supplements have been published in the N.A.H.T. Review, embodying the results of research on teaching methods conducted by an individual member or committee of members. Typical instances are ' Factors in Scholastic ability ' and ' Does the teaching of Grammar aid Composition ? ' Certain funds contributed as a memorial to Mr. Tibbey are available to assist educational research and grants are made to local associations of the N.A.H.T. that undertake definite research work (e.g. a grant of £10 has been made to the London Association which has investigated ' Variations in Test Performances among first year Senior Boys ').

The N.A.H.T. sponsored the attempt to form a research section under the ægis of the Royal Society of Teachers in 1935 ; they will most readily assist in the formation of a national research committee.

Associations that cater for a specific class of teachers naturally limit their inquiries to those problems with which they are most concerned. Thus the College of Teachers of the Blind has investigated and published (1932) *Syllabuses of Training for Technical Students in Handicrafts*, published by the Blind : they have also published *A Survey of the Education of the Blind.*

The Training College Association has recently published a memorandum on the *Training of Teachers*, compiled by the Joint Standing Committee of the T.C.A. and the Council of Principals. Its various sections publish periodically reports on methods of teaching school subjects, and accounts of experiments are reported in the T.C.A. *Bulletin* (e.g. in the issue of June 1938 appears a detailed account of an experiment with an environmental course at a Training College).

Other Agencies for Research.

The Committee feel that this survey of research carried out by the various agencies referred to above should be supplemented by reference to inquiries conducted by other organisations.

(*a*) First and foremost is the Board of Education : (*b*) mention should also be made of the Enquiry into Examinations, the International Bureau of Education and the Year Book of Education.

There are in addition individual teachers and others investigating various special problems in education, but adequate information as to their work is lacking. If the Committee have not emphasised the value of the researches by psychologists into the mental abilities of children, particularly in such matters as intelligence tests, this is only because they feel that justice has been done to the excellence of their work by such accounts as those given in the *British Journal of Educational Psychology* and the *Year Book of Education.*

(*a*) *The Board of Education.*—The Board of Education does not engage directly in educational research. The traditional English view of the functions of government departments is that under Parliament they should prescribe the broad outlines of policy and leave to local authorities, existing institutions and private enterprise as much initiative and liberty as circumstances permit. This is particularly true of our educational system, whose freedom from central control stands out in sharp contrast to the centralisation found in some other countries.

Nevertheless because the Board of Education does not exercise any responsibility for educational research, it would be wrong to assume that it is not interested in educational research or that it does not engage in educational research. The Board engages actively in educational research in so far as it is incidental to its administration, and its attitude to educational research on the part of others is in general one of friendly encouragement.

The two characteristics of research in the narrow sense of the word are the use of the inductive method and experimentation. Educational research of this kind implies a control of the field of experiment which the Board does not possess. The responsibility for conducting the schools does not rest with the Board, but with the local authorities and managing bodies, and the Board does not as a rule undertake experiments in the schools which would involve detailed control by the central authority of conditions which are normally under local control. Many kinds of research affecting schools and teaching thus naturally fall to local initiative, including that of the teachers, for instance experiments connected with methods of teaching. Occasionally also outside bodies make their own arrangement with the school authorities for securing the requisite facilities for conducting a research. When, however, in the course of administration, a problem of widespread practical importance is encountered in which schools and local authorities and the Board of Education all find themselves concerned, it is open to the Board to initiate and take joint action in conducting experimental work directed to the solution of the problem. An illustration of this is the research which the Board and certain local authorities have been together carrying on for some time into tests of capacity and attainment for the selection of children for transfer from the public elementary to the secondary school.

Research in the widest sense of the word includes investigation based on the inductive method but not involving experimentation. Educational research in this sense includes investigation in all parts of the educational field, not merely in administration and organisation, but also in the history, theory and practice of education. The Board's many activities in this connection are summarised in the following paragraphs.

The Board's Standing Committees, notably the Consultative Committee, the Adult Education Committee, and the Secondary Schools Examinations Council, have produced many well-known reports on educational problems based upon deliberations in which the sifting and review of the relevant facts has generally been an important element. The same applies to the Interdepartmental and Departmental Committees which the Board set up from time to time to investigate and advise upon particular problems. Some of the reports of the Consultative Committee are noteworthy, not merely in themselves, but also on account of the results of researches embodied in them, for instance the historical note on faculty psychology by Prof. Burt, the memorandum by Prof. Hamley on cognitive aspects of transfer of training, both printed as appendices to the Consultative Committee's recent report on Secondary Education, and the historical chapter of that report by Mr. R. F. Young, the Secretary.

The Board's Inspectorate is a highly qualified body of men and women with experience of teaching, whose daily work brings them into contact with the schools. Many investigations are conducted through them, sometimes through the Subject

Panels, and sometimes through the Inspectorate generally. The Subject Panels consist each of about 10 Inspectors who are experts in a particular subject, e.g. Science, Classics, Modern Languages, Infant Work, Domestic Subjects. An example of the results of an investigation by a Subject Panel is the Pamphlet on Optical Aids published in 1938. Examples of the results of investigations through the Inspectorate generally, leading to conclusions based on evidence drawn from the whole country, are the recent Pamphlets on Homework and on the Teaching of Backward Children. The results of the more general investigations are not always published, but are sometimes circulated through the Inspectorate and thus brought to bear on the work and practice of the schools. Typical questions which have been dealt with in this way in recent years are :

The teaching of handicraft, length of lessons.
Regional survey work as a form of practical geography and history.
Outdoor practical work in mathematics.
Science teaching, optimum size of the class.
The project method.

Above and beyond all this, the Inspectorate is continuously concerned with encouraging and noting experiments in schools. This is part of its daily work. The results are not necessarily committed to writing, but manifest themselves in the changing practice of the schools.

The Welsh Department of the Board controls a more compact and coherently organised body of inspectors, since the Principality is an administrative unit of convenient size presenting in its area, but in more manageable form, all the problems that concern their English colleagues, such as selection for post-primary education in rural and in urban areas. It appears to be the case that certain of the Welsh Local Authorities place special reliance on the guidance of the Inspectorate and this fact has enabled the Welsh Department to originate and develop experiments on two problems of particular interest to Wales with which no one else has hitherto dealt. These are the teaching of English in monoglot Welsh areas and the use of a form of Basic Welsh (in co-operation with the Orthological Institute) in bilingual areas. These experiments and the corresponding investigations are initiated and surveyed by the inspectorate.

The Board's Department of Intelligence and Public Relations conducted many investigations in the early days of its history, when it was known as the Office of Special Inquiries and Reports, and its reports not only made available for English readers a large amount of information otherwise difficult to get at, but served an even more valuable purpose in the way of suggestion and inspiration. The Department does not now itself undertake any systematic educational investigations, but amongst its many other functions it still plays an important part in initiating investigations, the Director being Chairman of the Committee which directs and co-ordinates the work of the Panels referred to in the preceding paragraph. The Department also includes the Board's Library of 80,000 volumes, which is easily the largest and most up-to-date educational library in the country, and an invaluable repository of information. The excellent facilities provided for readers are used by many research workers.

(*b*) The Committee feel that special mention should be made of the research in examinations carried out by *The International Institute Examinations Enquiry* (*England*). It was established in 1931 with the aid of grants from the Carnegie Corporation through the International Institute of Teachers College, Columbia University, New York. Parallel committees were established in five other countries and have carried on similar inquiries. Besides publishing an English Bibliography of Examinations and a conspectus of examinations, the Committee has published

An Examination of Examinations and *The Marks of Examiners*. The investigations already reported, notably those into the marking of subjects, have attracted wide attention and have incidentally served to confirm the need for the further research in examinations which is still proceeding under the ægis of this inquiry.

The International Education Bureau (*Geneva*) founded in 1925 has a membership open to all countries, educational institutions and other public bodies : it serves as an information bureau for all matters affecting education. The secretariat compiles documents relating to education, conducts research and institutes investigations into special questions. It holds annually a Summer Conference on Public Education at which reports are given of international inquiries and investigations conducted with the aid of specialists throughout the world. For this purpose much use is made of detailed questionnaires.

A similar organisation, though more restricted in scope, is the *International Bureau of Technical Instruction* which deals with problems affecting technical education.

The *Year Book of Education* has, since 1935, included a large number of reports on research into specific problems of education. The Institute of Education is editorially associated with the Year Book and the contributions are all by recognised authorities. In the 1939 issue abstracts of theses submitted for higher degrees in education at London University were included.

4. Possible Methods of Organising and Developing Educational Research in this Country. Examples from other Countries.

The Committee, having made the first general survey of educational research in this country, proceeded to consider suitable methods of organising and developing research.

Among possible methods of organisation and development the most fruitful appear to be :—

(i) A Central Council to direct and prosecute research.
(ii) The establishment of a Department of Educational Research either at some centrally situated university or else functioning as an autonomous unit.
(iii) A national committee to co-ordinate research and to supply information.

(1) Excellent examples of the first type are to be seen in the Councils for Educational Research for Scotland, Australia, New Zealand, South Africa and Canada. All of these except the Scottish Committee are similar in aims and constitution, with minor exceptions. The Scottish Council is a nationally appointed body enjoying support from the teachers and the Local Education Authorities and it is moreover a body directly concerned with carrying on research actively rather than stimulating or co-ordinating research. The other Councils are supported nationally but on a different basis and they are not so much concerned with prosecuting research as with encouraging and developing it. Moreover they make a special point of supplying information on educational matters and this is especially true of the South African Council with which there is associated a bureau of educational information.

At this point it will be useful to consider the constitution and functions of some of these Councils.

The Scottish Council for Research in Education.—This Council was established in 1928 as a result of the findings of a joint committee representing the Research Committee of the Educational Institute of Scotland and the Association of Directors of Education in Scotland. The E.I.S. accepted the main financial responsibility (£750 per annum) at the commencement, together with the Education Authorities (who subscribed £512 last year).

The Council is composed of thirty-two members nominated by the Association of Education Authorities (5), the E.I.S. (8), the Association of Directors of Education (5), the National Committee for the Training of Teachers (2), Training Centres and Colleges (4), The Scottish Universities (4), The Scottish Branch of the Psychological Society (2), The Association of School Medical Officers (2).

The Council, which was incorporated in 1932, has the following aims :—

(i) To initiate and control special investigations, making the necessary arrangements with the relative Education Authority.
(ii) To receive suggestions for research.
(iii) To allocate problems to suitable investigators.
(iv) Wholly or partly to finance approved investigations.
(v) To authorise the publication of results and recommendations, and to bear the cost (wholly) or partly of such publication.

It is governed by an Executive Committee of thirteen members ; there is a Finance Committee of five. The funds are derived from grants by the bodies represented on the Council and by contributions from individuals or organisations.

Since its inception the Council has undertaken a good deal of original research and has collaborated with other organisations for that purpose.

The research undertaken since 1930 includes research on standard tests for the Qualifying Examinations in Scotland, the curriculum in primary schools and for pupils of ages 12 to 15, secondary school pupils' attainments, environmental influence on mentality, mental surveys of rural and urban areas, visual aids, effectiveness of university entrance examinations. Two of its publications which have attracted widespread notice are *The Intelligence of Scottish Children* (1933) and *Achievement Tests in the Primary School* (1935).

The Australian Council for Educational Research.—This Council owes its inception to the Carnegie Corporation, for it was formed as the result of discussions initiated by an American professor visiting Australia in 1928 with a Carnegie visiting grant. Following those discussions a representative conference was called in 1929 which recommended the formation of a Council. The Carnegie Corporation voted for this purpose £5,000 annually for ten years with a further £2,500 annually for the first five years. The Council was established in February 1930 and the Executive Officer assumed duty in April.

The Council by the terms of its grants from the Carnegie Corporation must be 'independent of control by any university, state system of education or political party.' There are nine members, six of whom represent each of the State Institutes of educational research and three are co-opted.

The Council initiates research, supports investigations by approved students, teachers or administrators, advises investigators, supplies information and awards grants for observers to travel to the U.S.A. and to Europe. It sponsored the New Education Fellowship Conference in Australia in 1937. The Council has published fifty-one reports describing the results of various inquiries and researches, and retains a large number of unpublished reports.

The New Zealand Council for Educational Research.—This Council began operations in 1934 with a grant of £3,500 a year from the Carnegie Corporation. The Corporation suggested that the Council should avoid 'over-emphasis on research of a sterile sort. The Council should always feel free to give New Zealand a kind of service which is not ordinarily rated as research, a service which is capable of application in the professional field.'

A Council of seven was established (by the Corporation in the first instance) and has since been continued in office on the basis of one representative from the four local branches and three co-opted members. Its functions are similar to those of the Australian Council. To date it has published ten Research Reports and four

studies of New Zealand education. It also sponsored the New Education Fellowship Conference in New Zealand in 1937.

The South African Council for Educational and Social Research.—This was instituted in 1934 to administer a grant of £12,500 (payable over five years) from the Carnegie Corporation. It is associated with the parent body the *National Bureau of Educational Research* established in 1929 whose functions were (1) to act as a clearing house for educational statistics and ideas overseas as well as in South Africa ; (2) to act as a liaison office between the various education departments in South Africa ; and (3) to conduct research on educational problems and to co-ordinate such research done by universities and other agencies.

The Bureau is controlled and financed (£6,000 per annum) by the South African Government and acts as the executive office of the research council. Thus the Government and the Carnegie Corporation co-operate in educational research. This co-operation was initiated when the Bureau in 1929 at the request of the Carnegie Corporation undertook research on the subject of 'Education and the Poor White.' The position may be summarised by saying that the State maintains the National Bureau of Social and Educational Research while the Council supports research on special subjects for which the Carnegie grant is given exclusively.

The Bureau now operates five divisions :—

(*a*) Educational Research ;
(*b*) Social Research ;
(*c*) Psychological Research and Social Service ;
(*d*) National Library on Educational and Social Research
(*e*) Films.

Two conferences were organised by the Bureau—

(i) International Conference on Education under the auspices of the New Education Fellowship (1934), and
(ii) a National Conference on Social Work (1936).

The Bureau issues an annual Statistical Bulletin. The Council allocates grants for research under the five divisions noted above and is helped in this connection by an Advisory Board which meets annually. The Council has issued ten publications since 1936, embodying the results of completed research on such subjects as scholastic tests and native education.

The *Canadian Council* is in process of formation.

(2) The second type of organisation is the *ad hoc* institution or college of research of university standing which is exemplified by the *International Institute of Teachers College*, Columbia University, New York.

The Institute was established in 1923 to carry out the following objects :—

(*a*) to give special assistance and guidance to the increasing body of foreign students in Teachers College ;
(*b*) to conduct investigations as to educational conditions, movements and tendencies in foreign countries.
(*c*) to make the results of such investigations available to students in the U.S. and elsewhere in the hope that the pooling of such information will help to promote and advance the cause of education.

It publishes annually an *Education Year Book* which includes studies of education in various countries written around some special topic (e.g. for 1938 the theme was 'Rural education and rural society').

With the aid of the Carnegie Foundation for the Advancement of Teaching, the

Institute has sponsored various projects in Europe such as the inquiry into examinations (England, Norway, Finland and France) and an intelligence survey of children (Scotland).

It may be noted in passing that the Carnegie Foundation for the Advancement of Teaching has disbursed between 1924 and 1938 137 grants, totalling £250,000 for 82 projects in the field of higher education. Fourteen of these have been carried out in the offices of the Foundation, 68 under the auspices of other institutions.

The Institute is associated with Teachers College, which is a homogeneous unit of Columbia University in the same way as, e.g., the Imperial College of Science is a constituent college of London University.

(3) There is lastly the type of organisation which takes the form of a national co-ordinating Committee. This has been previously mooted in this country as mentioned on pp. 534 and 535, but the difficulties of establishing such an organisation have proved to be considerable.

Nevertheless there is an impressive body of opinion cited previously in favour of the establishment of such an organisation.

5. Recommendations and Conclusions.

This Committee has had to consider which of these three types of organisation would be suitable for England and Wales. They are of the opinion that the first type—a national council for the prosecution of research is not the most suitable type to establish for England and Wales. Realising the valuable work that has already been accomplished by the Scottish Council, and by similar councils in the Dominions, they feel nevertheless that as research in the widest sense of the term is already being carried on by so many agencies in this country it would be unnecessary to establish a directing council which would itself initiate and carry on research.

Many of the replies received in support of a national research organisation are in favour of co-ordinating research instead of the active prosecution of research. Several correspondents express the fear that the effect of the establishment of an *ad hoc* Research Council would be to diminish the spontaneous activity of Local Education Authorities and teachers in carrying out their own inquiries and researches. Those who are most active in research invariably support the principle of a co-ordinating committee in preference to an executive research organisation.

Similarly, the Committee do not think that a college or an institution for research affiliated to a university can be recommended as suitable. Any Council or committee or institution connected with educational research must, they feel, be linked up with the universities generally, and also with the local education authorities, the teachers' organisations and the educational associations.

It cannot effectively function as a unit devoted to a specific purpose. The tradition of English education is against central control or monopolistic activity. Greater benefit would be achieved if a central committee were to stimulate research and supply relevant information to all interested.

They feel therefore that what is wanted is an organisation that will co-ordinate research rather than undertake it, will register and record it, will prevent overlapping and guide individual workers or teams of workers to those fields of study wherein their inquiries can be most profitably conducted for the benefit of all sections of our educational system.

Accordingly they propose that a national committee should be established having those functions and in addition acting as a central bureau for information.

The functions of such a national committee would in fact be administrative rather than executive. Its control should be vested in just proportions among the supporting

bodies which include the universities, L.E.A.'s, teachers' associations and educational bodies. It should work in full co-operation with all of these ; it should maintain close co-operation with the Board of Education and keep in touch with Research Councils in the Dominions, the U.S.A. and Europe.

The establishment of such a national committee would, they are convinced, bring immense benefits. They do not underestimate the difficulties, chiefly financial, but they are impressed by the cordial goodwill with which the suggestion of such a committee has been received.

Proposals for Establishing a National Research Committee.

They realise that to bring such a committee into being involves the adoption of one of several methods :—

(*a*) The Committee or Council might be established forthwith on as widely representative a basis as possible. This course would necessitate comprehensive guarantees of financial support, as well as a precise definition of the council's functions. If an annual income of from £2,500 upwards were guaranteed, the Committee could commence operations with a reasonable certainty of ultimate success. It could not only record and register research, but assist research into urgent problems by allocating grants to experienced investigators. Its financial basis would have to be assured however. If it had no financial resources the Council would have to prove its effectiveness before it could expect financial support from other quarters such as Trusts and Endowments for educational purposes. But it could scarcely expect to establish its position and prove its effectiveness unless it had sufficient resources to guarantee a successful start. It is on this question of finance as much as on the practical difficulties of organisation that all previous attempts to develop educational research in this country have failed.

(*b*) Should the action contemplated in (*a*) above prove to be not immediately practicable owing to lack of funds, an alternative might nevertheless be available in the form of joint action between the representative Committee or Council referred to and some suitably placed university centre. The hope that some such way of proceeding might prove possible is strengthened by information brought to the Committee's notice of a project to establish a bureau of inquiry and research at the University of London Institute of Education. It is understood that the English Committee of the International Institute Examinations Enquiry—an undertaking which has continued since 1932 with the financial support of The Carnegie Corporation of New York, is about to terminate its activities. It is anxious, however, that the work of inquiry and research should continue, not only into questions concerning examinations but into other educational problems also. The Carnegie Corporation shares this desire and is accordingly prepared to make available a sum up to $10,000, provided that this sum is met by equal contributions from other sources.

The Examinations Enquiry Committee (under the Chairmanship of Sir Michael Sadler) is now engaged in an effort to raise at least £4,000 in addition to the grant from the Carnegie Corporation. Such a total sum, rather more than £6,000 at the least, might, it is felt, be sufficient to justify a three-year experiment.

Sir Michael Sadler's Committee proposes that the sum thus raised would be at the disposal of The Institute of Education for the purpose of establishing a bureau of inquiry and research. The Institute, it is understood, is prepared to receive and administer the money for a three years' period on this condition.

It is further proposed that to advise on policy an Advisory Committee should be appointed, representative of The Universities, L.E.A.'s, Teachers' Associations, and other organisations directly interested in educational research.

The administrative organisation at the Institute itself would be kept as small as

conditions permit in order that the bulk of the money might be available for the financing of research projects. Some would be expended on projects initiated and carried out by the bureau itself; the rest would be used to make grants to workers of proved capacity carrying out investigations approved by the Advisory Committee.

There is much to be said in English conditions for a limited experimental project on these lines carried out over a tried period before finally establishing a permanent organisation of full national scope. *Moreover, it is understood that if the experiment proves successful the Institute would be prepared to merge its interests in a permanent national organisation and would, indeed, conduct the bureau from the first with that object in view.*

Further, it would accept as its own Advisory Committee a representative body such as is proposed in (*a*) above. In this way there would be provided from the outset a link between the activities of the Institute's Bureau and the wider national interest.

(*c*) The scope of the above plan does not include provision for the *bureau of information* which is everywhere felt to be urgently needed. The exclusion of such provision for the present scheme springs not from any underestimate of its importance but rather from a sense of the magnitude of the effort involved. The funds likely to be available for the Institute would do no more than cover the costs of a central office and of a limited number of inquiries into questions of urgent practical importance.

The financing of an information bureau must thus be regarded under present conditions as a separate question, and one to which the British Association might well devote some thought and effort. Should such a bureau be established the two ventures could work in the closest co-operation under the guidance of the same representative committee and when the time arrives could be merged into one central office of information and research.

The Committee having considered these possibilities are of opinion that it is desirable to ascertain whether there is any general support in favour of one of these alternatives.

Recommendation.

They therefore *recommend* that as a first step the British Association should take the initiative in convening a representative conference to discuss ways and means of establishing a central committee for educational research and that this conference be held not later than December 31, 1939.

APPENDIX.

Copy of Questionnaire circulated to Local Education Authorities.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Committee of Inquiry into Educational Research.

Chairman :	*Secretary :*
Prof. F. Clarke, M.A.	A. Gray Jones, M.A., B.Litt.
Institute of Education,	29 Gordon Square,
University of London, W.C. 1.	W.C. 1.

..................April, 1939.

To..................................

Dear Sir,

The above-mentioned Committee has been set up by the Council of the British Association in order to investigate the possibilities of organising and developing research in education.

What is meant by 'Educational Research.'

The term 'research' is used in its widest sense, and includes in this connection not only formal investigations such as inquiries into examinations, intelligence tests, etc., but also experiments and inquiries about such matters as the curriculum and organisation of schools (including special schools), equipment, heating, lighting and ventilation, the relationship between physical training, nutrition and educational fitness.

Methods of Organising Research.

While the Committee have not come to any conclusion as to ways and means of organising educational research, they are generally in agreement that a suitable form of organisation would be that of a central council which would co-ordinate the activities of many autonomous bodies and should be in close touch with similar bodies in the Empire and in other countries.

Information Required.

The Committee as a first step are compiling information on the amount of educational research now being carried on under the auspices of your authority.

I should therefore be greatly obliged if you would kindly complete and return to me the enclosed questionnaire not later than May 20.

My Committee will gratefully acknowledge any help given by you in this matter.

I am,

Yours faithfully,

Secretary.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Committee of Inquiry into Educational Research.

1. Name of Local Education Authority.

2. Title and brief description of investigations, surveys or special inquiries carried out under the auspices of your Authority in recent years (say since 1929), the results of which might have a wider rather than local interest.

3. By what agency was the investigation, survey or inquiry carried out?

(*a*) By the L.E.A.
(*b*) By some other agency—

(i) with financial support from the L.E.A.,
or (ii) without financial support.

4. Would you favour the creation of an organisation, national in its scope, for the more systematic pursuit of such inquiries as for example are defined in the covering letter.[5]

5. Any other remarks.

Any printed or stencilled copies of reports on 2, 3 and 4 above would be greatly appreciated.

[5] The British Association is devoting attention to the form that such an organisation should take and will be glad to communicate later with you on this point.

SCIENCE AND SOCIAL PIONEERING

THE FIRST BRITISH AND AMERICAN ASSOCIATION LECTURE *

By Dr. ISAIAH BOWMAN

PRESIDENT, THE JOHNS HOPKINS UNIVERSITY.

The classic tale has man witless until he receives the Promethean gift of fire. Light and fire are the age-old symbols of the mystery of the creative force in man, or of what some would call the divine beginnings of man's discovery of a forward way. We talk less of mystery to-day for, if the source of the light of understanding is still unknown, man himself has successfully trimmed the wick. Reflected, dispersed, and recombined from thousands of mental and spiritual facets, the light reveals ever-new possibilities of adventure, experiment, and stimulating insight for the self-conscious creature, half angel, half brute, who talks endlessly about his elusive destiny. Whatever their own genius may be, all thoughtful persons borrow or reflect enlightening fact wherever they find it, and observe with alternating hope and anxiety the endless search by other men for that object of faith and labour called progress.

Reflecting in this fashion, it seemed to me presumptuous to express only my limited individual opinion in this opening address in an annual exchange between the British and the American Associations for the Advancement of Science. It seemed better to inquire of others what they would choose to say. Because scientists are apt to praise the children of their brains, the views of non-scientists were sought on the contribution of science to social welfare and to that uniquely human process of consciously planned advance across the threshold of experience which we may call social pioneering.

To that end I invited one hundred men who are not engaged in either physical or biological research or teaching to express their opinions. For special reasons two exceptions were made. The opinions are almost wholly American; I have included those of but a few English and French friends. The list includes lawyers, teachers, artists, poets, government officials, historians, economists, preachers, industrialists, left-wing and right-wing publicists, military men, bankers, and railway executives, as well as a member of the United States Supreme Court, a member of the President's Cabinet, public institutions of many kinds, men with power of command over others, and men who exercise power only through ideas. With few exceptions they are men whose names are well known on both sides of the Atlantic.

Each person was asked to set down not his studied or rationalised opinion

* *Owing to the premature termination of the Dundee Meeting, this lecture was not delivered.*

but rather his quick and customary response to the idea that science has or has not added to man's cultural possibilities, given him a better way of thinking through his difficulties, raised his hopes for a more ethical civilisation. Was his *habitual mode of thought* with respect to these propositions positive or negative?

To keep my promise to contributors the following twenty numbered statements, which combine the one hundred opinions, are given without references to sources. They are arranged in three groups—those which emphasise the gains (12), those which express qualified approval (5), and those which point to losses (3). No attempt has been made to give them consistency (compare, for example, items 10 and 5).

Emphasising the Gains.

(1) Science is to-day the most excited front of human enterprise, and such excitement is a good in itself. The fact that tens of millions of people are interested in scientific discovery and theory is one of the hopeful things in this Pandora's box of a time. Conceivably these tens of millions are or might become interested in a wider view of human affairs.

(2) The light that science has thrown on religion has made the difference between fearing God and believing in God, for it brings God within the sphere of personal experience. It has done this mainly through the removal of the fear of the supernatural. It has not lessened the force of religion by weakening the force of orthodox religion. There is neither an Acheron nor a seat of torture of souls: the shades are peaceful abodes. There is a proven moral law—that is good which experience has shown to be good.

(3) Science has enabled us to understand many catastrophic forces though we control or combat, with limited success, but a few. Thereby it has reduced the areas and much of the strain of ignorance, superstition, and myth. Forecast in several fields has entered so effectively into civilised man's thinking that it tends to stabilise both mind and act to a remarkable degree, giving a sense of permanence or at least assurance in the midst of obvious change. We no longer cower before 'the forces of nature,' at least intellectually.

(4) Science has encouraged specialisation, and specialised knowledge is the mother of invention. Both have greatly complicated life by making us all increasingly interdependent. In the past half century a multitude of new occupations has grown up employing millions whose livelihood is dependent upon multiplied wants and the complexities of specialisation and interchange that feed them. Science and invention, and commerce between the less civilised and the more civilised peoples, have encouraged a phenomenal increase in world population. 'Back to the simple life' would mean starvation for many of these millions: it would also mean additional manual toil for almost all of us as well as diminished comfort and security. There can be no *Erewhon.*

(5) Science serves an expanding civilisation but we do not know anything at all about our ultimate fate: the future is beyond conjecture: 'the end is forbidden.' If science has introduced dangers it has also made a net addition to human welfare by greatly expanding man's identification and use of natural resources. Humboldt's dream of 'enlarging the outlook of mankind' through

geographical study has been realised : the diversities of the earth have enriched life immeasurably. Synthetic chemistry has supplied a host of new products and opened gateways to still wider conquests afield. Like animal and plant breeding, it has changed the human potentiality in, and therefore the significance of, large parts of the natural environment. It has not destroyed geographical diversity, but it has become a factor in the rearrangement and revaluation of diversified resources.

(6) Science insists that *facts* are indispensable in the ordering of social change or reform. Though we proceed by trial and error to a large extent, it is science, especially the analytical use of statistics in the social field, that ruthlessly exposes error and helps to restrict the areas of prejudice and uninformed preconception. Sentiment and emotion have their place in the evolution of society from lower to higher but in themselves they are fallacious guides. Social programmes are put forward as tentatives or hypotheses if the scientific method is followed. In earlier times one could give categorical answers to all questions of objective and meaning. Science has eliminated much of the categorical.

(7) The effect of the doctrine of evolution upon modern thought in many fields has come to be incalculably great. It has revealed a far more complex universe than had been conceived under the assumptions of fixed numbers and kinds of species that in turn accorded with the simplicities of the geometry and the idealised astronomy of the Greek climax. It destroyed in time the over-generalised doctrine of universals in nature. It weakened the hold of metaphysics upon observational significances. It showed up the limitations of abstract logic in discovering or assimilating truth that is either essentially irrational or subject to change as new facts emerge and men are driven to make 'a fresh examination of particulars,' as Francis Bacon phrased it. It gave new meanings to both science and society by its revelation of a body of knowledge that drew its ordering from the historical record of the origins and evolutions of types correlated with the geological time-scale on the one hand and with experimental results on the other.

(8) Many of our social problems are ethical and in this respect the common man is perhaps the equal of the intellectual in balance, temperament, and insight, or even surpasses the insulated and stylised man who has the protective walls of an institution around him or the assurances of recognised social position or wealth. In these days of exaggeration, when mere political mechanisms tend to be worshipped as golden calves, the scientist at least knows that there is no collective salvation of souls and no final order. It is the business of science to discover truth, not salvation. In many instances salvation comes through the emotions and they are generally inaccessible to reason : it is also in large part an inner process, as Mazzini observed : 'You will not have things better until you are better yourselves.'

(9) Historically, the indebtedness of economic study to natural science is two-fold : replacement of the naïve premises of classical deduction by positive data, and the use of such data in facilitating the much-neglected but indispensable step in economic deduction, namely verification. The methods and objectives of political science have been re-examined under the inspiration of scientific influence. A healthy iconoclasm has ensued and the positive approach has become dominant. Historical writing has come to

have greater accuracy and objectivity, less emotion, prejudice and prepossession, and more convincing conclusions, but might not these qualities have been gained without the example of science?

(10) Public health has been promoted by progress in biology and biochemistry and by public acceptance of or demand for appropriate administrative measures. Out of the disaster of the Asiatic Cholera in the thirties of the last century arose the office of Registrar-General in England over which William Farr presided for a time. Concerning that event Dr. Parkes, an English hygienist, wrote: 'It is impossible for any nation, or for any government, to remain indifferent when in figures which admit of no denial, the *national amount of health and happiness, or disease and suffering, is determined* [our italics]. The establishment of the Registrar-General's office in 1838, and the commencement of the system of accurately recording births and deaths, will hereafter be found to be, as far as the happiness of the people is concerned, one of the most important events of our time.' During a discussion in Parliament in 1875 on the Public Health Act, described as the most complete code of sanitary law in existence, Disraeli said: 'The public health is the foundation on which repose the happiness of the people and the power of a country. The care of the public health is the first duty of a statesman.'

(11) The scientific attitude of mind is indispensable to further social progress but scientists should be more modest in their claims. However closely one investigates and measures there is always a gap at the end to be jumped by the imagination. The gap can be narrowed considerably by careful thought but after that one wants just knack or nose. Truth is deep down, said Democritus. In social applications of science one should be mindful of the precipitate of human experience which tradition represents as well as of the conflicting solutions and assumptions which we have inherited. Science itself does not supply adequate motivation for dedicated and unselfish living, living on a high level. If a scientist has these qualities it is because he is something more than just a scientist. Science has given a vast number of material satisfactions, but where has it left public thinking with respect to the heroic struggle without which a people has no fibre, no victory?

(12) Humanitarianism and democracy stand in the way of wider applications of science to social problems: they have permitted an enormous increase of population, with a rising proportion of biologically unfit and a rising standard of care for the unfit. Civilisation may be too much for *Homo sapiens*, but at least we keep on trying, and science is one of the ways of trying. At times the growth of large corporations has also stood in the way of wholesome social change. In the absence of any clear philosophy of control by society they grow past the bounds of public knowledge. While they have had well-know beneficial effects they also permit a modern form of ruthless raiding. A democracy is required that not only gives economic and political opportunity but also treats men as ethical and spiritual beings.

Qualified Approval.

(13) Science, largely by its emphasis upon the freest and widest inquiry, has aided in the diffusion and acceptance of the principle of religious and racial

toleration, but there is grave doubt of the strength and permanence of this gain.

(14) Lord Kelvin's remark that 'you do not know much about a subject until you have tried to measure it' is clearly applicable only to that which can be measured. Science deals quantitatively with measurable things and less with *quality* which supplies the essence of culture. With its emphasis upon a mechanistic theory of inevitable law, science has acquired a prestige that can be a real danger. The crucial question is, what has science done to enable the individual to *see* the pattern of his ideal more clearly and to *fulfil* his new vision? Measurement and accuracy do not touch even the fringe of social questions. The totality of human affairs (ideas, beliefs, conduct, habits, institutions, etc.) cannot be reduced to deterministic sequences. Knowledge of facts does not tell us what to do about them. *Social action is based upon assumptions, expressed or implied, respecting human values.* Science helps indispensably, however, in its zest for truth, for careful observation, for an even-tempered attitude.

(15) Science has shrunk the planet, close-knitted civilisation, and practically revolutionised life. Once we thought it remarkable that *news* from all over the world got to us each morning; now the distant trouble itself is at our door. While our curiosity has been widened, will anyone claim that our sense of responsibility has been enlarged? Are we usefully informed or only distracted? A high degree of accuracy has been attained by news services if methods and time limitations are taken into account, with the result that 'public opinion' has gained a status not unlike that of a world conscience. The dictators always lay hands first upon radio, cable, and newspaper. They wish the rest of the world as well as their own people to be unaware! Two chief difficulties delay the realisation of a better international order: (1) the increasing dependence of individual welfare upon a limitlessly expanding number of other individuals unknown to him as persons; and (2) the creation of an unbelievably complex web of human ordering beyond our present means of guidance.

(16) Very few people know anything about or care about science in a fundamental sense. The better a product becomes and the more widely it is used the less public interest is shown in its origins and mechanism. It is the æsthetic factor that now counts most in a motor-car: all cars run well. The public will continue to accept the findings of science but, if pushed too fast in the direction of new social schemes called 'scientific,' they will become frightened. Our time span for social change is now much shorter than formerly. In an earlier day more time was given to absorb change without conscious direction. Hair-trigger thinking is now fashionable in the social field, with action but an instant behind, and the revisionary habit of science applied to such thinking would have a desirable sobering effect. At present, applications are left to mediocre minds. Shamefully little progress is made towards the solution of basic social problems such as housing, access to medical care, stabilisation of employment.

(17) Universal education offers the only hope of establishing in the minds of the people the minimum conclusions of science that bear on social welfare most directly, or appear to do so. These minimum conclusions can become the blueprint of social engineering only if they are kept within the range of

mass thinking. That range, in turn, is limited because human desires are dynamic and simple, while human intellect is telic and complex. Desires propel, intellect can only feebly guide. ‘ People ’ see the *things* of science and forget the *discipline*. Their minds are littered by ideological concepts and dogmas, incapable of verification, that stand in the way of acceptance of a scientific approach to social problems.

Losses.

(18) We live in ‘ the dark hour of a gifted age.’ Science has made war more terrible ; it has debased mankind by its growing disregard for helpless and innocent non-combatants ; it has forced the whole of civilisation to adopt the most horrible methods of destruction. Men have tried to agree not to use the worst instruments of warfare, as the Church once tried (1139) to anathematise the use of ‘ the deadly and hateful art of crossbowmen and archers in wars against Christians and catholics ’ ; but in the end each new frightfulness triumphed.

(19) It is a clever, cynical, and hard-bitten world that science is making, one in which the idealistic and the spiritual are bound to have a diminishing place. Viewed against a background of classical education science has been a disadvantage to our society. If the most important questions of mankind are those concerning spiritual relations with one another and with God, then science is not to be taken seriously. Through dazzling discovery and successful practical application science gives a sense of power that is both demoralising and dangerous. We are given an enormous driving force that makes it more dangerous for us to be as bad or as foolish as we could be with impunity down to the middle of the eighteenth century. The impact of science on our morality, individual and national, is evil unless we rise successfully to the test of our character and moral traditions. Science has taught us analysis but we have had as yet no large-scale and equally successful synthetic constructions that bear on human conduct. The mass mind seizes and acts upon perverted ideas of scientific generalisation. Darwin’s ‘ survival of the fittest ’ encourages men to be brutal ; Freud’s ‘ don’t repress,’ to indulge their passions ; Einstein’s ‘ relativity,’ to think that truth doesn’t exist and doesn’t matter.

(20) The fickle wishes and caprices of men, in economics and government particularly, have been given weight and apparent rationality by the adoption of unsuitable methods devised by technocrats accustomed to weighing material objects. To limit oneself to ‘ data ’ in social studies is to parody society. Human science must think of life as a whole. The riddle of life is not in objects or discoveries without, but in conscience and mind within. A man’s ‘ destiny ’ is what he can make out of his own character.

‘ Science ’ is not a Universal.

In weighing these responsive observations one does well to keep in mind that what we call ‘ science ’ is largely though by no means wholly a conscious intensification of methods and results that had exceedingly remote origins. Science is a part of human life, not something separate and distinct.

Farmers of all centuries, fishermen, and especially sailing folk—all have developed science of a sort: empirical observation, limited analysis and generalisation, confrontation of theory (idea) with fact, as well as revision or modification (with much myth and nonsense built in too). The methods were not labelled or systematised, cause and effect were often wrongly ascribed, but the result was progress by taking thought.

It does no good to vaunt science as if it were something that stood above the rest of knowledge—independent, self-sufficient, worshipful. As human experience, science is not a universal, a summation of knowledge applicable and useful to the whole of life; it is rather a thing of limited categories. Science gains nothing by the decline of humanism: it is itself a special form of humanism. One asks, what is its net worth in the sum of human interests? What does it add to education, to outlook, to citizenship? And especially what does it add to human possibilities, to spiritual incandescence?

No claim for science may be set up without pointing to the limitations of scientists as individuals in responding to prejudice, group opinion, and the like. To most scientists, science is only a specialised form of experience. When a scientific man turns to the social framework which contains his science, conditions it, encourages or discourages it, he is bound to take account of other elements of society than his own, other tastes, other judgments of value in life. Individual scientists are often affected by the source of their support. They will tend to approve the policies of the companies that supply them with a living. They will measure a social programme by the yardstick of company prosperity. The company may be a profit-making concern or a university.

A scientific career, so-called, does not necessarily make its devotees broad-minded, cautious of the word, modest in spirit. It takes more than science to widen a narrow man's sympathies! Science does not in itself 'turn the common thoughts of life into gold.' Few scientists have the power of persuasive exposition; many have 'the gift of infrigidation.' Scientists have no monopoly of the power to discard dogma, the courage and intelligence to win territory from superstition. Do they call attention to the merits of scientific method 'to protect their banners and slogans' or to improve society?

The Concept of Change.

In so far as the methods of the physical and natural sciences teach patience, establish the value of both imagination and doubt, enhance analytical power, and provide training in observation, they are of value in any study—crime detection, historical inquiry, or the rise of contemporary social movements. But these are not powers newly acquired by scholars in our scientific age. They have always marked all research and insight, in antiquity as in recent times. The poet shares them with the scientist. What biology and geology have done is far more distinctive and new in thought than these qualities denote. They have made the Greek 'all flows' not only a matter of time, but also a matter of form and function—change as *the mode of the universe.* How and why things change is at the core of scientific inquiry, not alone how things are.

One of the greatest achievements of science is its emphasis upon free inquiry—the mind itself in command, driven by curiosity and the sense of

intellectual adventure. The motive force in an earlier day was faith which removed 'not mountains only but the whole material environment.' Facts and events were removed from the realm of human action to that of divine grace. Theology and philosophy have since been modified, largely by the light of modern science. Evolution has required every intelligent religion to reshape its view of man. Recent pragmatic philosophy would have little substance if the evolutionary concept were subtracted. After 1860 historical writing clearly showed the effect of the evolutionary approach; and economic theory dealt increasingly with the problems of a dynamic society. The doctrine of evolution involved the minds of men in what can be conservatively described as an overwhelming revolution. In the eighty years since the *Origin of Species* was published no thinking man has escaped its influence.

The concept of evolution influenced some areas of thought long before the modern doctrine of biological evolution was formulated. It was a maxim of Roman law that the limit of the law is its greatest injustice. To codify the law and put it into 'tables' represented progress; but it was greater progress to take it out of the tables again, so to speak. Precedents had been proven to be not enough; ethics and public utility were asked to determine forms, and ethics and public utility change with time and circumstance. The whole body of Roman Law reflects an effort to apply reason and fairness to a changing society to be accommodated by an elastic set of rules in which the danger of definitions was pointed out. Principles were made to rest on experience; they were 'rooted in a philosophic consideration of human life.'

In the natural world no such progress was made in Roman times and indeed we do not see how it was then possible. Lucretius showed what science (as he understood it) could do but he was unable to make practical proposals for social applications. An understanding of nature would drive fear out of the world, said he, and a better knowledge of both nature and the gods would help bring peace and honour to men. Only as late as our time could the principle of evolution be so variously documented that the idea became accessible and interesting to all men, not the vision of a few. Each specialist came to see fruitful applications in his own field. Dynamic change displaced ideal pattern, fixity, and immutability. Lawyer, economist, historian, geographer, priest, chemist, and statesman could speak a common language of movement, of continuing adaptation, through nature and through interactive society.

Diversities and Contradictions.

Civilisation may be usefully considered as an adventure in change. New forces are generated through the evolution of tools, the domestication and subsequent breeding for quality of animals and plants, through age-long folk experiment, and through the occupation of new lands with their diversifying possibilities. Each people carries on the adventure in a different way because of its distinctive regional environment, its unique aptitudes, and its variant objectives and philosophies.

The diversities of time, place, and race may also raise barriers to understanding. Confluent in trade and travel we are nationally divergent and often discordant with respect to philosophies and ethics. Our rules are not the

same, in Asia and America. Our languages are no more unlike than our systems of logic, or our definitions. Our ethics and our judgments also change in time. It is sometimes said that ethics and manners are matters of geography. In this fluctuant world the geography changes rapidly also, because as man changes his techniques, his tastes and his systems, so also does he change the *significance* of much of his environment.

The main job of some schools of agriculture is to raise food-production per acre. This is condemned by those who say that we grow too much food already. It is praised by those who, as in over-populated Puerto Rico, are trying to get the value of food crops per acre raised to the level of the sugar crop, now 800 per cent. above food crops in value ! The Netherlands East Indies tries to meet the reduced demand of world markets for her staple crops (rubber, sugar, coffee) by new crops—tung oil from plants imported from China, tanning material from an Acacia imported from South Africa, wood-pulp from imported pine trees. The ultimate values and distributions of men and resources are unknown to us : we suspect there are no ultimates. We keep learning in the hope of achieving net improvement for the time being. We have also learned that to learn is generally to change.

Most public discussion is babble about agriculture, industry, health, education, security, employment, taxes, war. The voter is asked to express opinions on a jumble of political and social programmes by casting *one* ballot. One item in the bundle may be desirable, another highly undesirable. What effect will an act in one field have upon desired ends in another field ? The whole must be dealt with and the individual knows only a small part.

Specialisation increases Satisfaction.

Science and much dependent invention has added to our material equipment to so great a degree that it has given ' standard of living ' the magnitude of a major social force. The individual desires to possess maximum satisfaction, and nature is explored, invention hastened, productive techniques refined to that end. Public health is improved and education made general, in order that life may be more *satisfying*. Fabrics of high utility and pleasing colour and design are now available at more generally attainable prices than formerly. The illustrative arts have opened new worlds of enjoyment to millions. Photography alone has vastly increased the satisfactions of mankind. The gains in food production are revolutionary. Quick-ripening wheat and rust-resistant wheat represent two epic breeding struggles with billions of dollars worth of human welfare at stake in the empire of the Canadian North-West alone.

Let no one dismiss the gains of science lightly with the word ' material,' as if that didn't matter ! We cannot overlook the unrelenting fact that all but a few of the people in the world *must* think about food and clothing and power, muscular and otherwise, in order first of all to live. Only a protected life provides the time and strength for continuous thought about meanings, discovery, philosophy, æsthetics. The genius alone may be an exception—the miller's son who became Rembrandt, the ploughman Burns.

The scientist no less than the humanist sees the smallness of the spiritual gains in deplorable contrast to the material benefits. What we are trying to

do, said one who helped develop Crater Lake National Park, about the forested rim of a high circular bowl in which lies one of the loveliest of the blue waters of the world, is to offset speed. When it took a day to reach the place, people enjoyed it, after earning their enjoyment. Now they rush up to the top in an hour in swift motor-cars, dash to the rim, gasp 'My God, how blue it is!' and rush right down again!

The Edge of the Possibilities.

Science has become one of the greatest of the adventures of our time partly because it deals with the edge of the possibilities. Man was always working to push past limits, but much new knowledge, and vast organisations in our day, have speeded up the process. Man has also discovered that he is changing his own possibilities as well as those of his world as he goes along. He is at the centre of his own creative experiment. He has found that what science supplies is not at all an addition, positive and beneficial, until men have proved it so. The whole of that proof is in man himself and not in admiring regard for new facts and inventions. Things and forces, social and natural, good and bad, are added to himself, with the result that ever new possibilities are emerging.

Land pioneering to-day illustrates two such interacting forces—the edge of the possibilities (marginal land) and the desire for an acceptable standard of living. The limits of land cultivation are being traced farther and farther afield. But what is left of pioneer land in the twentieth century is marginal land whose conquest requires both knowledge and better material equipment. The pioneer, seeing himself as part of a wider community, asks for a share in the total benefits. If he is to be empire builder he wants his reward here and now. So, let government do it. Roads, schools, telegraph lines, favourable freight rates, market facilities, low taxes, and security from undue risks to health on the frontier are demanded! The protection of children brings restrictions, limitations, conservatism. Things must get better in time or too many families will become habited to the backward look to optimal regions.

Science here serves as a supplement to marginal nature—what crops are adapted to uncertain rains, or late-spring and early-autumn frosts, long haulage, and distant demand. If the frontier environment cannot be supplemented, social deterioration will take place. It is not enough to push people out upon the land if the land is marginal, risky, remote. Civilisation must accompany the settler. Finally, the intending settler must have the will to succeed and he must have the capacity to adapt his musculature to new physical tasks, his mind to the possibilities of new cultural (social) experiments on the frontier, his enterprise to the potentials of the land and the region. If spirit is wanting, if security and accustomed ways are indispensable, if adventure is dead within him, the frontier is no place for him, with or without science.

New Frontiers in Old Communities.

In the United States applied science has increased agricultural production per worker, through machinery and fertilisers chiefly, and speeded transport, with the result that agriculture has become dominantly commercial and

competitive, with marked changes in crop production and type of farming in many regions. Civilisation has become increasingly urban with resulting weakening of both family ties and the neighbourhood bond. Machinery has helped create more commerce, more striking and more numerous economic successes, and a much higher standard of living for certain classes. Billboards on the highways tell youth that it is 'entitled' to a good car, good clothes, a good time. Whether or not that entitlement was earned, what responsibilities go with it, what the advertised product will do to strengthen character or enfeeble it—these things are not put upon the billboards.

We have learned how to feed and breed animals to a high level of efficiency. We expect six thousand pounds of milk a year from a single cow to-day, whereas a hundred years ago two thousand pounds was the average. We know how to preserve food for long transportation. We successfully combat many plant enemies. We have done work upon the grasslands to preserve and improve them, upon soils to determine their rate of wastage and the extent of their need for conservation, upon fisheries as a food source for man. We have calculated the amount of ocean that will be required to sustain a man: a volume of sea water approximately equal to that of a football field covered five feet deep with water and requiring two and a half hours to filter out the zooplankton. If the result seems economically not feasible, science may yet find a way to strain sea water in the likeliest places and provide additional food. Here taste and preference may step in. Will a breakfast of copepods become popular even though we know that they are equal to the best meat in nutritive value?

The triumphs of a scientific age have coexisting population problems of a disturbing character. In the large cities of America there are now about 7 children to 10 adults. If our present reproduction rate remains stationary these 7 children would raise 5 children and the 5 in turn would raise about 3½. The middle class in the cities consistently diminishes its stock. By contrast, the farm population raises about 14 children to 10 adults; the 14 would have at the present reproduction rate about 20 children and the 20 about 28. In 1937 and 1938 the 'farm-baby crop' increased, the total for 1938 being the largest since 1926. How long and with what stock will the farm help populate the city? Not enough children are being born to maintain the existing level of the population of the United States. Already the enrolment in the first grade of the public schools has fallen about 100,000 a year since 1930. In the six elementary grades it is declining about 200,000 a year.

It is not easy to point out offsetting conditions to farm population decline. The electrification of farm operations, the development of credit unions and producers and consumers co-operatives may restore a sense of mastery to and lay a basis for cultural participation by those who are drawn into the struggle that tends to pull good stock to the cities, there to confuse and devitalise it culturally, morally, economically. Between 1790 and 1930 our rural population increased twenty times while our city population increased three hundred times!

The play of the forces involved in these far-reaching movements and cultural changes, whether self-initiated and free or guided by government, denote a pioneer fringe of high interest in the social field. The situation needs vital leadership, courage, and local pride as well as equipment and the experimental

point of view. These are old-fashioned virtues and they imply the hard way. Can our entire population rise to such Spartan levels, to self-denying activity, to ideals of independence and strength that evoke dynamic enthusiasm?

Individual and Group.

It is a fallacy to suppose that *group energy* is the sum of the individual energies in the group. A man does not make war: a nation or a tribe makes war. A citizen with a gun and no licence and a soldier with a gun have two quite different social prospects. A group approves group action which it may condemn in the individual. Our social ethics are not consistent with our personal standards. We are caught up by our generation in the world at large—its ideas, its wars, its conflicting loyalties.

Our culture has developed dysgenic rather than eugenic qualities. Success and its social rewards, implying unusual intellectual and other social capacities, have become linked with diminished fertility. The well-endowed are not reproducing on an adequate scale. This means a steady diminution in the supply of the inherited qualities that brought success. In so far as success is spurious or anti-social the loss of these inherited qualities need not be regretted. In so far as it represents socially valuable qualities it means continued erosion of human character and loss to the race and to civilisation.

We are wanting in general acceptance of categories of socially useful qualities. 'Eureka, I have found it' means nothing socially until all have found it. 'The genius raids . . . the common people occupy and possess.' Whatever we gather of scientific knowledge concerning society and how it might be improved is one thing; to persuade or to exercise control in order to bring about desired ends is quite another.

We say that youth should be taught to acquire power to adjust itself to associative living. To a large extent this means the acceptance of the standards of contemporary society, the routine encouragement in one's self of that which society encourages. To carry this out to the fullest extent might be to destroy individual gifts and powers. Social living is not all! Will society foster or permit the not-understood individual variations that include the genius?

The supposition that scientific discovery can be made to bear immediately upon social change, the scientist remaking society, seems faulty doctrine. 'Society' is built upon beliefs, traditions, prejudices, suppositions, and philosophies, as well as facts, institutions, inventions, and materiel—all supported by power or force exercised through *time*. Every advance in applied science calls for a tighter and more inclusive social organisation, and it is the state which inevitably controls that organisation. In exercising its controls, the state (consisting of determined *groups of men* who hold power, no less than accepted but precarious forms of controls, institutions, and the like) may introduce only those discoveries that suit its book. The holders of power, to whom power is the first law, will scarcely legislate themselves out of office. Moscow, Berlin, London, and Washington are alike in this respect.

What is unlike in these four countries is a far more profound thing—the relative degree of freedom for the individual in finding and proclaiming scientific discoveries and in *advocating* their social applications or acceptance. The fight for adoption or rejection of ideas is in the open social arena in

democratic countries. If there are dangers we are free to denounce them : no philosophic theory of society stands in the way. By contrast, if it suits the dictator to rest his social argument upon the powerful effects of an improvised environment he rejects the findings of geneticist and eugenist and even a Vavilov loses his job. To be secure as a scientist in a totalitarian country one must first ask a political bureau what is sound.

Let no one suppose, however, that democracy ensures continued freedom. Only when democratic social control of economic life is fully extended shall one be able finally to test the hypothesis that freedom of learning can live in the house of democracy. If the gap between ' knowledge ' and folk thinking gets too wide we shall all have to turn to the forging of a common method of thought, with no small risk to be run that a sterile generaliser with power may impose a philosophy. This makes the conservation and freedom of the minority a vital need : how often has a single vigorous challenge saved a human situation !

Planning involves Risk.

The tentative nature of social conclusions is often a deciding factor in the rejection of scientific findings. Rightness is not proved except through social experiment that is jeopardised by too short a period of trial, by misrepresentation and misunderstanding of effects, by the fact that the objects of experiment, men and women, care for different kinds of outcome and such caring may change the outcome. Speed in social reform itself creates a kind of road hazard because of unpredictable turns and their effects, unforeseen impacts and disturbances.

The long view and the short view are difficult to distinguish—a further complication. To preserve our civilisation we strengthen our nation, pointing to the competitive situation in the world at large. Through national planning we seek to raise the level of health and strength, to solidify national interest. This will inevitably have the effect of intensifying international competition. Commerce is increasingly competitive and necessarily implies inequality of opportunity in specific lines. In a wide sense commerce is the mother of all wars.

In the international field the triumphs of increased home production, ersatz, and autarchy, hailed one by one as proof of growing independence and enhanced welfare—all are advantages that are bought at the price of dislocations elsewhere. Many a national triumph implies a setback for some other nation.

Identification of Causes precedes Control.

Social pioneering has to do with culture in the making, with environment that becomes understood by thinking about the conditions of trial and the effects of error. It deals with inevitably new social forms or old forms adapted to new situations, and becomes ever more complex and overpowering for the individual. Faced by an emergency we develop emergency measures only to find ourselves shackled indefinitely by the emergency forms which we set up, ' thereby covering up the conditions that necessitate them.'

The first duty of an intelligent society in the modern scientific period is to get at the causes of things. The increase in the general consciousness that

wonders exist, that science can create marvels, and that science supplies valuable elements in social living is a gain of the first importance. It has taught whole peoples to look for causes or to expect that causes will be found. Man's greatest hope lies that way to-day. Once causes are located there is no guarantee that a situation produced by a given cause may come to human control. But there is at least *a chance*! Any gains made in this field have appealing potentialities: a basic discovery generally leads to a host of derivative discoveries.

The scientific method is needed nowhere so much as in the sorting of causes and the delimitation of the action of forces supposed to be at the root of our troubles. The United States Bureau of Investigation reminds the Boy Scouts that though they number 1,281,000 they are outnumbered four to one by the 4,750,000 murderers, thieves, burglars, embezzlers, arsonists, kidnappers, extortionists, and other criminals. Equally the criminal hosts outnumber the college population of 1,200,000. The director of the Bureau does not find the cause of this appalling condition in science: he points to the skulking despoilers and modern-day pirates, 'the venal and corrupt politicians' who place personal profit above the rights of decent citizens. But what does he find in the decent citizens themselves? Apathy, lack of interest in honest law enforcement, laziness in the exercise of the power of the ballot. The underworld counts upon these qualities!

A recent advocate of 'glandocracy' contends that a society is as good or as bad as its nervous system and its glands, which together make an integrating mechanism whose character profoundly conditions the individual and his attitude towards the society of which he is a part. Given a harmoniously integrated development and the instinctive reactions to good social conditions are more likely to be adaptive and harmonious. Too simplified and mechanical an explanation, one may say. But in any event science deepens the understanding of basic conditions, and searches endlessly for causes in the hope that once they are found a clue to control may follow.

Breaking the Frame.

In man's endless adventure in progress, are the objectives to be great works of art, literature and science, or the development of personal health, strength, and hardihood joined to national conquest, thereby exalting the nation at the expense of the individual? Or is it sufficient to promote the glory of God by confession, by religious adoration?

Modern science is not without its infective transcendentalism. 'Our destiny is in our hands . . . develop all [our] potential activities . . . reject all systems,' says Carrel, who believes we can achieve almost illimitable social advance if we but give scope to feeling and genetic possibilities. He advocates resistance to 'the tyranny of the quantitative.' He would break the frame of the school, the factory, and the office, and reject the very principle of technological civilisation: mechanical inventions but hinder human development. This seems to overlook certain prime and as yet ineradicable troubles of mankind, such as divergent and conflicting aims, faults of organisation, lack of wide social participation in the findings of science.

How resolve the conflicts between classes, reduce the arrogance of

nationalism, and diminish the chances of war? Which class is to benefit most from a given programme, which nation? Are these questions any nearer settlement because of our present wealth of scientific knowledge? Would more scientific knowledge decide the correct and just apportionment of advantages and privileges and accessions to the forces that raise the standard of living? Without modern scientific knowledge would acceptable solutions be any nearer?

Justice to conflicting groups requires either agreement between them or a universal judge. Our sympathies are weak when we try to put ourselves in the places of men who are far away. We rationalise our own acts to make them good to us and those of the enemy to make them bad. When we fight for the good against the bad it is war nevertheless. Science should provide an even-tempered attitude, but it seems almost superhumanly difficult to cultivate it in society.

We believe in scientific progress, but we reject the findings of science if they disturb an existing going concern, a satisfied community, an assured communication method. We can see only a little way ahead. This produces caution in some. Others exclaim, 'if there are remote consequences let our progeny struggle with them.' To feed unemployed people we incur a debt. We assume that the fed are worth feeding, knowing that a good deal of unemployment is non-discriminatory. We say that a minimum degree of support is required for an unemployed person, but is not 'minimum' determined by worth? If we needed more people would not 'worth' rise? Will our children be willing to use the lesser wealth of their time to pay for the judgments of our time? Or do we act like the worker wasp that, when the food supply runs low, bites off the tail of the grub to feed to its head?

In the midst of our troubles, the endless search for simplicities goes on! The despairing layman's answer to the complexities of phenomenonology and doctrine is to set up or accept a new doctrine that is simple and clear and based on authority. There is a clamour for simplicity in economics, politics, and education. One hundred books will educate you and all educated men will then talk alike; a formula can surely be found to break down the barriers to unemployment; if all nations would embrace the principle of world co-operation we should have peace. Editorials, columnists' comment, articles, adjuration, philosophies, tend toward simplicities: ha! here at last is the prophet who has found a way!

There seems to be no straight path to a social goal; evolution seems chancey; progress is only a fitful by-product, says the despairing observer. Our loyalties waver, our beliefs change, our confidence in accepted democratic methods is impaired as we observe the wide variation of intelligence, the difficult task of sustaining interest in community affairs, the low level of individual satisfaction, the little knowledge we have of our leaders, the prime difficulty of bringing democratic method down from a glowing historical abstraction to a concrete activity, the inevitable performance of many functions of government by individuals employing their own judgment, the large element of guesswork in all forms of experiment, including social pioneering, the difficulty in distinguishing between true and false results in short or long periods of time, the haphazardness, the waywardness, the *lack* in democratic judgments, perceptions and actions. To offset these tendencies we offer education, more

science rather than less, and ' a documented call for action ' based upon agreement as to facts by social scientists. Little enough, one must admit.

Analysis and Advance.

Social forms cannot keep pace with creative thought. A time lag is inevitable because we have found no way to teach and test ideas except through time-consuming and often inconclusive experience. No one subject of study is capable of solving the total array of problems of a people. Science is no more deficient in this respect than social studies themselves. Hear an economist : ' Economics is not the science of welfare . . . it is concerned with the relationships of scarce means to given ends.' Economists may formulate economic policies through the application of reason and systematic thought to a limited field of human relations ; but economics cannot provide a total social programme, continues Mackintosh. Even the data and hypotheses of economics are limited to a particular age. The subject tends to become less general in its application, a doctrine rather than a science.

In the last quarter of the nineteenth century, modern economic analysis (Marshall, Jevons, Menger and Walras) found a tool of investigation whose focus is the principle of equilibrium and its use has been continuously extended ' to attack equally problems of disequilibrium.' When the economist is finished with his statistical analysis, he adds imagination, experience and reason to create and test his hypotheses. Are there institutions to carry out an indicated policy ? Will the democratic group for which it is designed understand it, accept it, and expand it to fit changing conditions ? The ends that society has in view are constantly changing and only rarely are they precisely defined. The problems themselves are complex and so, too, are the methods by which they will be solved, whereas public attention is short-lived and public analytical power is extremely limited.

Directives and Limits.

From the evidence of palæontology chiefly it was discovered that life from the first had both plasticity and the potentiality of change. Whatever the underlying causes and mechanisms, increasing complexity of form and function has been life's mode. Both muscular and psychological complexity has given organisms increased power (efficiency) in the *use* of the physical environment. Will the process stop with defeat at the physical and psychological assembly known as man, or will the conscious human turn his unique power of understanding upon himself, both as an individual and as part of a social mechanism ?

Faith and method joined to imagination and curiosity, still lead us on. Science is the greatest inciter of hope that we know—rational hope that the triumphant methods that have given us deeper understanding and increased efficiency as biological and social mechanisms, will one day give us a still deeper insight into who and what we are and what we may become when rational control is extended. As in art and religion so in science—new meanings evolve as the mind continues its unshackling process. The eternal is not brought down from aloft only : it is also sought out and raised up among men. Science is one way of acquiring a knowledge of meanings or of adapting or inventing meanings that give deep human satisfaction—for a time.

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Printed in England at THE BALLANTYNE PRESS
SPOTTISWOODE, BALLANTYNE & CO. LTD.
Colchester, London & Eton

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OF SCIENCE

(Founded, 1831. Incorporated by Royal Charter, 1928)

A SCIENTIFIC SURVEY OF

DUNDEE AND DISTRICT

PREPARED FOR
THE DUNDEE MEETING 1939

BY VARIOUS AUTHORS

Edited by
R. L. MACKIE, M.A., B.Litt.,
Training College, Dundee

The Supplement consists of the first five chapters of 'A Scientific Survey of Dundee and District,' prepared for the Meeting in accordance with the practice of recent years. These surveys, since their initiation in 1932, have been issued to members attending the Meetings, and have subsequently been included in the Annual Reports. The intention in future is to include the survey for the forthcoming meeting in the July issue of 'The Advancement of Science' preceding such meeting; whether that scheme will be possible next year, however, cannot be forecast. Meanwhile, it is intended to include further instalments of the Dundee Survey in following issues.

CONTENTS

A SCIENTIFIC SURVEY OF DUNDEE AND DISTRICT

I.

DUNDEE IN ITS REGIONAL SETTING

BY

S. G. E. LYTHE, M.A., SCHOOL OF ECONOMICS, DUNDEE.

THE geographical setting of a town is often easy to describe in print but difficult to illustrate in photograph. With Dundee it is rather the reverse, for whilst Dundee lies in a region of contrasts and complexities, topographical, economic, and ethnological, its geographical setting can be seen with somewhat startling clarity at the end of a climb up the Law, the great hill 572 feet high, which dominates the site of the town. Such hills are characteristic of certain Scottish towns, Stirling, Edinburgh, Perth with its Kinnoul Hill commanding the Tay valley, are a few examples. To climb or drive up the Law is the best introduction to the geography of the central parts of eastern Scotland. Immediately below lie the chimneys and roofs of Dundee. There seems to be no arrangement, none of the concentric rings normal to industrial-commercial towns of this magnitude, but even this human mishandling cannot disguise the beauty of the site. Travellers, from Queen Victoria to H. V. Morton, have unanimously agreed that there is nothing very " Bonnie " about Dundee except its situation, and the way in which the site has been occupied is the strongest possible argument for town planning in the future. To look away from Dundee itself in any direction is to pass from confusion to grandeur. Immediately to the south is the Firth of Tay with its vital but, unfortunately, single-purpose bridge, and beyond that the Fife hills with the sands of St. Andrews away to the south-east. Westward the Tay narrows as it approaches the hills of Perthshire, which sweep round to the north into the Grampians with their profusion of Gaelic-titled peaks. In the foreground to the north are the Sidlaws, with their highest point, Craigowl, almost due north of the Law and six miles distant. The intervening lowland, of somewhat indefinite character, suggests trees and arable fields and farmhouses. " This," says one of the most popular travel authors, " is the vision that Dundee men carry with them to the ends of the earth. No wonder that they always go back there some day."

The difficulties of delimiting geographical regions need no emphasis, but regional studies of the British Isles show some unanimity in attempting to handle the Midland Valley of Scotland as a main region divisible into several sub-regions. The unity of the Midland Valley is more evident in historical than in physical geography. It has always been the nucleus, economic and

political, of the Scottish nation, and as Prof. Ogilvie has pointed out, the continuous independence of Scotland until the 17th century may be explained, in part at any rate, by the relative immunity of the Midland Valley from border warfare and attacks from England. This Midland Valley is bounded by two lines of structural weakness, which, running south-west from the neighbourhood of Stonehaven and Dunbar, display the usual "Caledonian" trend. The rocks are mainly sedimentary, for the valley was a basin of deposition of the Old Red Sandstone and later occupied by a shallow arm of the Carboniferous Sea. These sediments are greatly confused, and in close association with them are found intrusions of igneous rock which have shown greater resistance to denudation than the sediments and consequently determine the more prominent surface features of the region. Thus the topography of the Dundee district is dominated by the Sidlaws and the Ochils, both composed of igneous rocks.

The geographical area with which we are especially concerned may thus be regarded as the north-east part of the Midland Valley, and whilst its exact bounds must remain ill-determined, a sub-division may be suggested as a basis for more detailed study :—

(1) The northern corridor of Strathmore.
(2) The Sidlaws.
(3) The coastlands of Angus and the Carse of Gowrie.
(4) The northern parts of the Fife Peninsula.

(1) Strathmore.

Strathmore is a synclinal trough, greatly altered by glacial action, and covered with thick deposits of stiff boulder-clay, glacial and river gravels, and recent alluvium. Entry at the northern end is via a strategic defile controlled by Stonehaven, but once inside the strath there is complete freedom of movement, for much of the bottom is below 200 feet, and remarkable uniformity of structure and scenery. Between this low trough and the Highland scarp is a relatively narrow shelf ranging about 400 feet high, the remnant of a higher peneplain, but cut at intervals by cross valleys leading to the Highland glens. Its front edge is marked by settlements, such as Alyth (1,662) and Kirriemuir (3,326), which command the Highland roads. These settlements originated as centres of trade, as points for the exchange of the products of regions with different physical qualities, but with the decline of the Highland trade, they turned their energies to industry, especially textile manufacturing. With the concentration of industry in places better situated for fuel and sea-borne traffic they have sunk into relative insignificance, except where revival has come through rail or road tourist traffic. As Mr P. R. Crowe has observed, they are excellent examples of the theory that a situation favourable for modern tourist traffic is often no more than a new interpretation of the old trading advantages.

The drainage of Strathmore is to several outlets, in the north-east the Bervie, then moving south-west the North and South Esk, the Lunan, Dean Water, the Isla, and finally the Tay. The first four drain eastwards directly to the sea ; the others south-westward to the region of Scone, where the Tay, which they have now all become, begins its great hairpin bend back to the east. The watershed, lying in the Forfar-Kirriemuir locality, bisects one

of the two groups of lochs which occupy hollows in the glacial drift. Of this eastern group Forfar Loch, about 105 acres, is the largest. Like most of the others it is shallow, though it was both deeper and more extensive before the cutting of an artificial drain to Dean Water. The western group, more numerous and extensive, lies to the south of the Coupar Angus-Blairgowrie-Dunkeld road. Many others have disappeared, either through natural accretion or through drainage for the exploitation of the shell marl which was formerly much used as a fertiliser.

Partly through its soil and climate, partly through its intermediate position between two relatively infertile areas, Strathmore is an important agricultural region, which for centuries exported its surplus produce through Dundee. Naturally, therefore, the towns along the centre of the trough, Coupar Angus (1,893), Forfar (9,659), and Brechin (6,840), developed industries for working up local raw materials and catering for the agricultural population. Coupar Angus especially retains its agricultural character. Forfar and Brechin have developed a wider outlook, due first to their royal and ecclesiastical links, and subsequently to their part in a wider field of economic activity.

For some 25 miles the strath is bounded on its southern edge by the Sidlaws, but this face of the hills, the dip-slope of the lavas, is smooth and gentle compared with the sharp, craggy escarpment which overlooks the Firth of Tay and Dundee. The main centres of population in this part lie at the foot of the hills, generally where transverse valleys encounter one of the longitudinal routes along the strath. Newtyle and Glamis are good examples of this type of settlement. The growth of the former has been closely connected with the railway link with Dundee which follows one of the most important transverse valleys. The early date of this line, 1826, may be taken as indicative of the volume of trade between agricultural Strathmore and the consuming and exporting centres to the south.

Strathmore may thus be described as a lowland trough with rich and sometimes specialised agriculture, with settlements ranging up to the market or small industrial town class in well-defined arrangement, a region which suffered in the past from inadequate drainage, but which, throughout history, has been of continuous strategic and economic importance as a route from the " waist " of Scotland to Aberdeen and beyond.

(2) The Sidlaws.

The Sidlaws mark the eastern extremity of the volcanic hills of the Midland Valley. The configuration of the hills themselves and the neighbouring eminences is determined by the distribution and thickness of the lava-flows. In the east, where these thin out and are separated by lines of sandstones, the Sidlaws form ridges with intervening low ground ; in the higher central Sidlaws sheets of intrusive dolerite have broken through the sandstone, giving the irregular terraced appearance to some of the hills such as Auchterhouse and Balluderon, which reach a height of nearly 1,500 feet ; to the south excessive denudation has completely exposed the roots of the old plugs —at Dundee Law, Balgay Hill, Tealing, and so on. Where the volcanic rock is exposed it weathers into irregular peaks, but generally the hills are long and smooth-backed owing to ice action, and partly clay-covered. Much of

the north-western face has a poor peaty or stony soil, and is mainly a forested or heather district. The southern terraces, on the other hand, have a lighter, dryer loam, and cultivation is found at a height of over 1,000 feet. As a rough generalisation it may be said that the limits of the various vegetation belts are 200 feet higher on the southern than on the northern slopes.

Settlement in the Sidlaw range has been determined by altitude, by lines of communication, and by the nature of the soil. There are still, for example, extensive mosses and peat bogs, though some have been reclaimed. The influence of lines of communication is perhaps most marked in the eastern Sidlaws, where two distinct lines of settlement coincide with two main routes. In this part life depends mainly on mixed farming and quarrying, further west grazing becomes increasingly important. The volcanic hill rampart, of which the Sidlaws form the eastern end, is pierced by a series of gaps, guarded by Dumbarton, Stirling, Perth, and Montrose. Montrose belongs rather to the coastal part of our area, but its position on the lowland strip between the Sidlaws and the coast may be noted here. Perth (34,807), the second most important city in this part of Scotland, occupies a vital strategic position at the lowest road-bridge point on the Tay, between the Ochils and the Sidlaws, and in close and easy contact with Strathmore. For centuries it rivalled Dundee both in land and sea commerce, but lagged behind as Dundee turned more and more to sea trading and ships increased in size. It has, however, developed a very considerable industrial life, and remains a gateway to the Highlands, both for goods and people.

(3) The Coastlands of Angus and the Carse of Gowrie.

The first of these two sub-regions, which can conveniently be treated together, lies east of Dundee and south of the Sidlaws. The landward part has many features in common with Strathmore. Generally speaking, it is a region of gently undulating surface with many wooded knolls, and drained to the south and east by little streams such as the Dighty, some of which have played an important role in the development of the linen bleaching industry. The soils are generally rich, often a mixture of boulder-clay and volcanic debris, which, in this area at any rate, implies great fertility. The glacial formations in this part, such as the long smooth hills a mile long and 500 feet high north of Strathmartine, mark the west to east movement of the Highland ice-sheet which crossed Strathmore and over-rode the Sidlaws.

In many respects the seaward edge is the more interesting part of this sub-region. Part of the coast is exposed to the sea, part to the relatively sheltered Firth of Tay ; in some places the water is fringed by shelving rocks, in others by shifting sands ; so that within a few miles can be found examples of accretion, erosion, and artificial reclamation. The north-east gales fling the waves obliquely against the friable sandstone near Arbroath, the debris drifts along the coast and some settles in inlets between its point of origin and Carnoustie, but the greater part travels in suspension until it encounters the outward currents in the Firth of Tay, where deposition takes place. In this way Buddon Ness, a pointed promontory similar to Dungeness in Kent, has been built up to narrow, but also to protect, the entry to the Tay. Between Buddon and Broughty Ferry both accretion and erosion take place. According to the Royal Commission on Coast Erosion, 56 acres were lost and 46 gained

between 1850 and 1911. The erection of groynes at several points since that time has no doubt retarded the rate of movement. Still further west lie extensive artificial reclamations, extending westward beyond the Tay Bridge. In the 19th century the Dundee Harbour Trust spent three-quarters of a million pounds on the reclamation of 188 acres for docks and warehouses, whilst the Town Council has carried out works of almost equal magnitude for recreation grounds and similar purposes, between them completely obliterating Dundee's original waterfront.

Two other features of this coastline deserve notice here, the sand-dunes and the raised beaches. The former are much in evidence in the Carnoustie-Barry Links locality, and where grass-covered they have been converted into golf links, artillery ranges, or rough pasture. The most conspicuous of the raised beaches is now 21 feet above sea-level. It stretches almost without interruption from Arbroath to Dundee, but varies greatly in width, attaining its maximum in the broad plains of Barry, where it covers 10 square miles. The 50 ft. terrace is much less distinct. The greater part of Broughty Ferry is built on it, but generally denudation has caused it to merge into the lower terrace so that a gentle slope has replaced the step formation. The 100 ft. terrace, actually higher in the west than the east, is conspicuous behind Barry. It consists of stratified sands and gravels on a ledge of denuded boulder clay.

The settlements along this coast display progressive domination by Dundee from east to west. Broughty Ferry, Monifieth (2,984), and Carnoustie (4,806) are all in a measure satellites, though retaining some activities of their own. Arbroath (17,635) and Montrose (10,196) are both populous and remote enough to carry on a much more independent life, each with a definitely industrial flavour and catering respectively for a tourist and military population. Subsequent studies in this volume will deal with many aspects of the life and economy of Dundee (175,585), and it would be presumptuous to attempt a summary here. We may note, however, that Dundee has attained its present stature without the advantages of a populous or wealthy hinterland such as that behind Liverpool or Newcastle. In spite of a long and close relationship both with the neighbouring parts of Angus and with the more remote Highlands, modern Dundee looks outward, towards the industrial centres of England and towards India. The relatively small area covered by the "shopping centre" of the town and the comparative obscurity and tardy development of its higher educational institutions reflect not some shortcoming on the part of the inhabitants, but rather the absence of any definite social and cultural hinterland which would look upon Dundee as its focus.

Even the Carse of Gowrie, immediately west of Dundee, is divided in its loyalties between Dundee and Perth. This sub-region, in Professor Ogilvie's words, is "a district apart." From time immemorial its productivity has bordered on the proverbial: "a plentifull countree," wrote Hardyng in the time of James I., "of corne and catell and all commodities." The Carse has one of the most fertile heavy loams in Scotland, formed mainly from the estuarine clays which cover a foundation of peats of typical Boreal composition. The productivity of this belt is due partly to the soils and partly to its sheltered position at the foot of the steep southward face of the Sidlaws. Its economic activities, like those of the Angus coastlands, are based on mixed

farming, but coloured by the proximity of two cities with an aggregate population of 200,000 and by the fruit preserving industries of Dundee and Montrose.

Along the level surface of the Carse communication is easy, and the situation of Dundee was determined partly by the intersection of transverse routes over the Sidlaws with a main coast route along the terraces north of the Tay. The Carse remains an important rail and a vital road thoroughfare to Dundee, though the latter function would lose much of its importance by the erection of a road bridge lower than that at Perth.

(4) The Northern Parts of the Fife Peninsula.

Whilst Fife clearly falls within the scope of this survey, the relations between it and Dundee are less intimate than mere distance would suggest. Until the late 19th century the Tay below Perth formed an almost complete barrier, crossed only by river ferries, at best a poor substitute for a land route. Indeed, the development of the Fife peninsula down to fairly recent times was dominated by two factors, of which this isolated position was one. The other was the marginal character of the chief religious and trading settlements, and though hard work has converted the interior into good farming country, " a beggar's mantle fringed with gold " is still a not inapt description. Despite the fact that modern Dundee has important economic contacts with the coalfields of south Fife and the linoleum trade of Kirkcaldy, we may justifiably confine the present study to the northern part of the peninsula which lies more directly within the social and commercial orbit of Dundee.

Northern Fife is essentially the Ochil region. These volcanic hills, closely related in structure and substance to the Sidlaws, run from the Firth of Forth to the Tay, thus severing the Fife peninsula from the rest of Scotland. The higher and more conspicuous parts of these hills lie to the south-west of the Dundee area, where they form two distinct ranges with several summits of over 2,000 feet and separated by a longitudinal valley drained by the head-waters of the Devon. Glendevon cuts across this system and at that point the longitudinal valley disappears. Ten miles north-east of Glendevon comes another transverse, dropping to below 500 feet. To the north this drains by the little river Farg, to the south it opens into the lowlands near the watershed between the Howe of Fife and the Loch Leven basin. With Glenfarg ends that part of the Ochils which can properly be called mountainous: the importance of Glenfarg as the first low crossing place east of Strathallen is a key fact in the human geography of the region.

East of Glenfarg the hills sink to below 1,000 feet and come close to the Tay. The settlements north and south, Abernethy (1,154), Newburgh (2,152), Strathmiglo (1,561), and Auchtermuchty (1,747), all occupy sites of a familiar nature, and are linked by roads which cross the hills and converge on Falkland, once a residence of the Scottish kings. Eastward again is another transverse linking the Howe of Fife to Newburgh and the Tay and holding the small Lindores Loch. Thence the hills again divide into parallel ranges with a longitudinal valley, followed both by a road and by the old Newburgh and North Fife Railway. The northern range rises to Norman's Law (936 ft.), then sinks to wooded eminences above Tayport (3,164), and finally ends above the sand-dunes of Tents Muir. The southern range rises to and ceases

in Lucklaw Hill (625 ft.), around the base of which the longitudinal valley drains away to the River Eden.

To the south of these eastern limbs of the Ochils lie Stratheden and the Howe of Fife, as that part of the strath west of Cupar is generally called. These form a relatively low-lying plain, crossed by busy road and railway systems, with Ladybank and Leuchars as the main railway junctions. The soils are mostly heavy loam with scattered patches of gravel, drained by streams which come from the Ochils and the Lomonds to form the Eden. After meandering north-eastward the river passes through a bottle-neck at Cupar (4,595), a market-town now famous for its beet-sugar, where the hills of the East Neuk press northward towards the low spurs of the Ochils. Thence to the sea the valley is narrow, and the muddy, winding estuary finally emerges between the wide raised beach of Tentsmuir, mainly a heather-covered expanse of fixed dunes, and the links of St. Andrews (8,269). Here, where so much of the religious, academic, and sporting tradition of Scotland is embodied, this survey may well conclude.

II.

THE GEOLOGY OF THE DUNDEE DISTRICT

BY

Professor D. E. INNES, St. Andrews University.

The relation of the topography to the geological structure of the district shown on the accompanying map is comparatively simple. The Grampian Hills, formed of metamorphic rocks, lie to the north-west, and are separated from the Highland Border Series and the Lower Old Red Sandstone by the Highland Boundary Faults. The rivers of the Isla and the Earn have cut their valleys out of the softer Lower Old Red Sandstone sediments, resulting in the former case in the capture of the older consequent streams descending from the Grampians. Lower Old Red lavas, occurring in a broad anticlinal fold, give rise to the Ochil Hills which open out to the north-east into the Sidlaw Hills, and the hills of north-west Fife and south-east Angus. The river Tay cuts through the Sidlaws east of Perth, and after being deflected by the southern limb of the anticline for a matter of sixteen miles, breaches it between Tayport and Broughty Ferry. Between these two anticlinal limbs sediments of the Lower Old Red Sandstone outcrop, with patches of Upper Old Red Sandstone faulted down at Balruddery, Clashbenny, and at Dron, where representatives of the Lower Carboniferous are also included.

The Lower Old Red Sandstone was folded and denuded before the Upper Old Red Sandstone was deposited on the upturned edges of the lavas, but the junction is concealed in Fife under Pleistocene Drift. The relatively soft beds of the Upper Old Red Sandstone have given rise to the plain of Kinross and the Howe of Fife. To the south-east, the Upper Old Red Sandstone either passes up into, or is faulted against, Lower Carboniferous sediments into which dolerite sills have been intruded; whilst numerous volcanic vents are scattered throughout the area. The dolerite sills and some of the limestone bands give rise to escarpments, whilst the vents often produce conical hills such as Largo Law.

The Lower Carboniferous sediments dip under the grits and Coal Measures of the Leven tectonic basin, and another Coal Measure area is preserved by faulting in the neighbourhood of Kinglassie. The district presents evidence of severe glaciation as shown in the moulding of the hills and by the deposits of sands, gravels, and Boulder Clay, which spread over the low lands and creep up to the higher ground.

The Carse lands bordering the Tay and the Earn, the valley of the Eden, and much of the low ground flanking the coast-line are covered by deposits belonging to the period of the raised beaches, together with fresh water alluvium, peat, and blown sand.

The Highland Border Series.

This Series can be sub-divided into two groups which are separated by an unconformity. The lower group consists of shales, grits, jaspery phyllites, and spilitic lavas, with basic and ultrabasic intrusions. The upper group or Margie Series is composed of grits, shales, and limestones. The Series is exposed at various places along the line of the Highland Faults, and the lower group has yielded brachiopods, etc., at Stonehaven and Aberfoyle, and is presumably Cambrian in age. Crinoid plates and calcareous algae have been found in the Margie Series at Upper Donans, and this group has been ascribed to the Ordovician.

The Lower Old Red Sandstone.

Including the abundant contemporaneous volcanic rocks, the thickness of the Lower Old Red Sandstone deposits of Angus and Perthshire is probably about 17,000 feet. The sediments consist of sandstones, shales, marls, and conglomerates, the last showing an interesting variation in lithology according to their stratigraphical level. Thus the lowest beds, forming a basement breccia exposed close to the Upper Ericht, are characterised by angular pebbles of quartzite, jasper, and other rocks derived from the Dalradian and Highland Border Series. At a somewhat higher horizon the pebbles in the conglomerate consist mainly of rhyolite and other acid volcanic rocks. These beds are later succeeded by other conglomerates in which basic volcanic pebbles predominate, and in the highest conglomerate belt there is a reversion to rounded pebbles of quartzite, schist, and other rocks similar to those occurring in the basement breccias. In the southern part of Angus conglomerates are not generally so extensively developed as close to the Highland Border, and sandstones, flagstones, and shales predominate. The Carmyllie Group of sandstones and flagstones contains, towards the middle of the Series, the main fossiliferous horizon, from which numerous species of fossil fish, Eurypterids, and primitive plants have been obtained.

The great development of contemporaneous volcanic rocks interbedded with the Lower Old Red Sandstone sediments may conveniently be divided into three groups, with in all probability different centres of eruption. (1) The Highland Border Region where the lavas are mainly of andesitic composition, but in the lower part of the sequence the eruptives are rather more acid than the average rocks of the great lava-piles towards the south and east. (2) The lavas of the Montrose centre reach a thickness of several thousand feet, but thin out towards the north-east and south-west, where the flows become intercalated with sandstones and conglomerates. The rocks consist mainly of enstatite-basalts or andesites, with and without olivine; there are no associated vents, the main centres of eruption probably lying under the North Sea. (3) The main volcanic pile of lavas, tuffs, and agglomerates forming the Ochil and Sidlaw Hills reaches in the neighbourhood of Stirling a maximum thickness of over 6,500 feet without the base of the lavas being revealed. Augite, hypersthene, and enstatite andesites form the common rock-types, with biotite-andesites and dacites in the North Fife Hills, whilst great spreads of volcanic tuff and conglomerate occur to the south of Newburgh. In all the volcanic areas agates, chalcedony, etc., are abundant in the vesicles of the lavas.

Intrusive igneous rocks of probable Lower Old Red Sandstone age are well developed within a circle of nine or ten miles radius of Dundee, where sills, dykes, and plugs, as well as more irregular masses, are represented, and a large part of the city is founded on igneous formations of this character. Petrographically the intrusions show considerable variation, consisting of quartz-hypersthene-dolerites, Balgay Hill, Den of Mains, Rossie Hill-Lundie; augite-porphyrites, Dundee Law, Craigie; ophitic basalts, south of Glamis and at Auchterhouse Hill; tholeiites, Auchterhouse and on the site of the old Dundee prison. Oligoclase-porphyrites occur in the railway cutting at Seabraes, west of Dundee, where the corrugated roof of the intrusion has domed the overlying sandstones. Similar rocks occur in Fife at Lucklaw Hill and at Peashill Point, Wormit, the latter being associated with intrusive breccias. A quartz-diorite intrusion is found at Glenduckie Hill, three miles east of Newburgh.

Conditions of Deposition.

The Lower Old Red Sandstone sediments were formed under semi-arid conditions to the south-east of the Caledonian mountain ranges, the sandstones being partly of fluviatile origin and partly formed in temporary lakes. The conglomerates represent torrential gravels which were swept down from the hills and spread out over the lower ground, whilst the lavas were erupted from volcanoes situated in the foothills or scattered over the plains. Fine sediment was frequently washed into cracks and cavities in the lavas, forming veins and pockets or lenticular intercalations between the flows. Towards the close of Lower Old Red Sandstone times the area was subjected to earth-movements with the formation of the Strathmore syncline and the Ochil-Sidlaw anticline, followed by a long period of denudation.

The Upper Old Red Sandstone.

Deposits of this age underlie the Howe of Fife, whilst outliers in the Carse of Gowrie have been preserved by trough-faulting along the crest of the Ochil-Sidlaw anticline; other exposures are to be seen on the coast at Arbroath, Boddin Point, Montrose, and St. Cyrus. Sandstones, marls, and conglomerates form the bulk of the sediments, but cornstones may be developed locally as at Boddin Point. The most famous section in the Fife Upper Old Red Sandstone is that cut by the Ceres burn in Dura Den, where in former excavations great assemblages of fossil fish remains were found crowded together at one horizon in the yellow sandstone. The species discovered included representatives of Bothriolepis, Phyllolepis, Glyptopomus, Holoptychius, and Phaneropleuron.

The Carboniferous.

A. The Calciferous Sandstone Series.

The Upper Old Red Sandstone sediments, where the junction is not faulted or obscured, pass up conformably into the basal beds of the Calciferous Sandstone Series, but it is difficult to decide where the dividing line should be drawn. Between Fife Ness and Randerstone Castle, and again between Cambo Ness and Kingsbarns Harbour, a series of red and green clays and shales, sandstones, cornstones, chert, and andesitic conglomerates occur.

These probably represent passage beds between the Old Red Sandstone and the Carboniferous, but the base is not visible and their relationship to the overlying Randerstone Beds is obscured by faulting. The sediments of the Calciferous Sandstone Series in East Fife consist of alternations of sandstones, shales with ironstones and cementstones, fireclays, coals, and limestones; the most complete exposure of this Series is to be seen between Anstruther Harbour and Coalfarm, east of St. Monans, where the Hurlet or Coral Limestone outcrops on the foreshore. Here, according to Mr J. W. Kirkby's table, about 4,000 feet of strata are exposed, and include a number of limestones and shales crowded with lamellibranchs, gastropods, entomostraca, etc. At a depth of 2,280 feet below the Coral Limestone occurs the zone of the "Encrinite-bed," which is also exposed repeatedly on the foreshore between Buddo Ness and St. Andrews. The highly fossiliferous Randerstone Beds are bounded by faults, but their probable equivalents in the Anstruther section lie about 1,000 feet below the horizon of the "Encrinite-bed." The Calciferous Sandstone Series thins rapidly to the westwards, and is represented by only a few feet of strata at the Lomond Hills, whilst beds of "Cementstone type" have been preserved by faulting at Dron, near Bridge of Earn. There is a marked absence of evidence of contemporaneous volcanic activity of this age in East Fife as compared with the district between Burntisland and Kirkcaldy.

B. The Carboniferous Limestone Series.

This Series is sub-divided into the Lower Limestone Group, the Limestone Coal Group, and the Upper Limestone Group. The base of the Series is considered to lie about 20 feet above the Hurlet or Coral Limestone of St. Monans, which is quarried for the limekilns at Cults. The Lower Group consists mainly of shales and limestones, with interstratified sandstones, fireclays, and thin coals. Locally the limestones are known as the Hosies, and afford indications of having been deposited in rather clearer water than those of the Calciferous Sandstone Series. The Limestone Coal Group extends from the top of the Top Hosie Limestone to the base of the Index Limestone, and consists of an alternating series of sandstones, shales, fireclays, coals, and ironstones. The principal coal seams are worked in the neighbourhood of Dunfermline, Lochgelly, Kirkcaldy, and Markinch. The Upper Group indicates a return to marine conditions similar to those under which the lowest group was deposited. The strata consist of sandstones and shales, with the Index Limestone at the base, the Calmy Limestone near the middle, and the Castlecary Limestone at the top. Thin seams of coal occur and are workable in the Capeldrae district; whilst the interstratification of ashes and sediments in the neighbourhood of Largo points to contemporaneous volcanic activity.

C. The Millstone Grit and the Coal Measures.

The Millstone Grit, as exposed between Pathhead and Dysart, consists of gritty sandstones and conglomerates with shaley intercalations, and passes up gradually into the Coal Measures of the Leven and Kinglassie coalfields. The Coal Measures can be divided into two groups, the Lower or Coal-bearing Group, consisting of about 1,700 feet of sandstones, shales, ironstones, fireclays, and workable coal seams which appear to have been

formed in situ. Near the top of the group Mr Kirkby discovered a band of marine fossils similar to those which occur in the Carboniferous Limestone Series. Musselbands referable to the lower Similis-Pulchra zone occur near the top of the Lower Group, and the Ovalis zone is represented by a band above the Dysart Main Coal. The Upper or Barren Red Measures are composed of red and white sandstones, shales, fireclays, and a few thin seams of coal.

Conditions of Deposition of Upper Old Red Sandstone and Carboniferous Sediments.

The conditions prevailing in the earlier part of Upper Old Red Sandstone times were somewhat similar to those obtaining in the Lower, but as subsidence and deposition proceeded, shallow continental basins were formed, in which the sediments were partly of fluviatile and partly of lacustrine origin, and were often subjected to periodic desiccation. The passage to the Carboniferous was gradual and was mainly determined by local conditions, but early in Calciferous Sandstone times periodic marine invasions took place over East Fife. The bulk of the sediments appear to have been deposited in lagoons, or shallow coastal flats, which emerged at intervals to give rise to coal measure swamps, or sank beneath the sea. The greatest submergence is recorded by the Hurlet Limestone, when the sea covered most of the Midland Valley and was clear enough for the formation of banks of the coral Lithostrotion. Deltaic conditions probably occurred at the time of the formation of the Billowness Sandstone in Calciferous Sandstone times, and again in the Millstone Grit period. Towards the close of the Carboniferous the swamps in which the Coal Measures were deposited must have largely dried up, for the upper part of the Barren Red Measures appears to have been deposited under semi-arid conditions.

Igneous Rocks of Carboniferous and Permian Age in East Fife.

A. Volcanic Vents.

The large number of volcanic vents which are scattered about the district appear to be confined to the Carboniferous area. They vary in ground plan from circular or elliptical outlines to irregular or dyke-like forms, and are filled with basaltic agglomerate or tuff together with a certain amount of sedimentary fragments, but in some cases the igneous material is wanting. Around the margin of the vents the strata often shows signs of having been bent or faulted down towards the pipe, whilst the larger vents may contain masses of steeply-dipping bedded ash, due to the sliding of material into the orifice during periods of quiescence or after extinction. Plugs and dykes of basalt, often showing columnar structure, frequently penetrate the vent material and the surrounding strata, and may be so completely filled with basaltic and sedimentary fragments as to stimulate agglomerates. The lava varies from an olivine-basalt, with monoclinic pyroxenes and low felspar content, to a monchiquite; analcite and nepheline may be present in the groundmass, whilst xenocrysts of soda microcline, hornblende, biotite, augite, and olivine segregations are sometimes present. The mineral assemblage in some of the vent materials resembles that of the "Blue Ground" of the South African diamond pipes. Certain vents in the neighbourhood of St.

Andrews pierce the local anticlines in such a way as to make it appear that these necks must be of later date, but the age of these folds is uncertain. The vent at Lundin Links, which cuts the Coal Measures, some containing rounded quartz grains, and possibly the necks including quartz-dolerite fragments, appear to belong to the Permian Period.

B. Dolerite Intrusions.

These occur as sills or dykes which can be separated petrologically into two distinctive groups, the quartz-dolerite- -tholeiite suite and the teschenite- -theralite suite.* The main sills of the former group lie roughly west of a line from Leven to Guard Bridge, and the olivine-dolerites, etc., of the latter group lie to the east of this boundary. Dykes of the quartz-dolerite- -tholeiite suite, with the characteristic E-W trend, are common in the Old Red Sandstone area to the west, and a quartz-dolerite dyke cuts vent material two miles east of St. Andrews. On the other hand, fragments of quartz-dolerite are found in certain of the vents, and a volcanic neck pierces a quartz-dolerite sill on the Lomond Hills.

Folding and Faulting.

The coast-section from Fife Ness to Dysart commences low down in the Calciferous Sandstone Series, and gradually ascends through a repetition of anticlines and synclines to the Coal Measures of the Leven basin. The sediments displayed on the foreshore between Fife Ness and St. Andrews belong to the lower part of the Calciferous Sandstone Series, and do not ascend much higher than the zone of the "Encrinite Bed," but in both cases the sequence is repeatedly interrupted by minor folds, faults, and volcanic vents. Certain local folds and faults occurring in the neighbourhood of the vents must be due to the volcanic eruptions, whilst others are considered to be of an igneo-genetic character dependent on the intrusion of the dolerite sheets or sills. The main folding which gave rise to the broad anticlines and synclines must have taken place in late Carboniferous or Permian times, but the age of the local folding has not yet been conclusively determined. Normal, reversed, and transcurrent faulting is represented, and one of the latter, with N.E.-S.W. trend, has shifted the vents in the neighbourhood of Elie. The throw of the faults varies from a few inches to several thousand feet, but it has not so far been found possible to trace the major faults for any great distance with certainty. It is probable that the transcurrent faults of N.E.-S.W. trend are later than the E.-W. faults, and may represent the last phase of movement in the district; the majority of the faults appear to be Permo-Carboniferous in age.

Pleistocene and Recent.

There is abundant evidence to prove that throughout a large part of the Pleistocene Period the area was subjected to intense glaciation. The general alignment of the glacial striae on the lavas of the Ochils, and the dolerite sills of East Fife, is from west to east, but towards the coast of Angus the direction of movement was north-easterly. Examples of "crag and tail" are numerous,

*For the distribution and petrology of the rock-types see list of references given in British Regional Geology, The Midland Valley of Scotland.

as on Largo Law, where the boulder-clay lies 700 feet up on the seaward slope, but hardly 300 feet above sea-level on the landward side. Erratics are found all over the district and consist of Carboniferous rocks, Old Red lavas and sediments, and gneisses and schists from the Highlands. A tough unstratified boulder-clay covers a large part of the area ; it contains sub-angular striated stones similar in composition to the erratics, but rocks, whose origin is obscure, are sometimes found in the clays. Evidence of an interglacial period is recorded from Kincardineshire, but nothing of this nature has so far been discovered in Fife.

Phenomena connected with various stages in ice-retreat are well developed in the district, such as overflow channels, kames, eskers, and the remains of temporary ice-dammed lakes. The fluvioglacial and glacieluvial deposits at St. Fort are over 200 feet thick, and their base extends to forty or fifty feet below sea-level.

According to evidence obtained by J. B. Simpson, a late readvance of Highland ice took place down the Teith valley and upper Strath Earn to form a " Piedmont " glacier which reached the late-glacial sea in the region of the Firth of Tay. It seems probable that about the time of the " Perth readvance " the sea-level stood approximately 100 feet above that of present mean-tide, and that the shell-bearing arctic clays of Errol, Carse of Gowrie ; Guard Bridge, Seafield, and Elie were formed about this time, together with the sands, gravels, and erosion terrace of the 100 foot Raised Beach. The arctic clays represent the off-shore or estuarine equivalents of the 100 foot beach deposits, and often contain fragments of chalk, flint, and other Cretaceous rocks, whilst at Errol the fine brownish-red clay contains occasional boulders dropped from floating icebergs, and shells of types indicating very cold conditions such as occur off West Greenland at the present time. The 100 foot beach varves at Dunning in Strath Earn are considered by De Geer to have been formed rather more than 13,000 years ago. The coastal 50 foot Raised Beach probably represents a temporary halt in the recovery of the land, which finally emerged until it stood slightly above the present sea-level. To this period can be ascribed the peat deposits, containing remains of birch, alder, willow, hazel, and pine, which occur on the coast and up the estuary of the Tay. After the Submerged Forest Period the sea-level rose and the 25 foot Raised Beach was formed. It is the best developed of all the beaches and forms an almost continuous terrace from Elie to St. Andrews, where it underlies the Links and the sand-dunes of Tents Muir. The Carse clays and the deposits underlying the blown sands of Barry, Carnoustie, and Montrose also belong to this period. In the Carse of Gowrie the mudflats rose to a rather higher level, and estuarine silts were deposited in which Neolithic implements have been found. The final fall of the sea to the present level probably took place some four or five thousand years ago. An investigation of the tide levels recorded over the last hundred years at Dundee harbour indicates that during this period the land has remained stationary.

D. E. I.

In the preparation of the above brief account of the Geology of the Dundee District the following books and papers have been consulted :—

The Geology of Eastern Fife, 1902. Sir A. Geikie.
The Geology of the Country Around Dundee. British Association Handbook, 1912. R. M. Craig and D. Balsillie.

East Fife. Proceedings of the Geologists' Association, Vol. XXXVIII. (1927), pp. 453-469. D. Balsillie.

Scottish Carboniferous Stratigraphy. The Transactions of the Geological Society of Glasgow, Vol. XVIII., Part III. (1928-29). M. Macgregor.

British Regional Geology. The Midland Valley of Scotland, 1936. M. Macgregor and A. G. Macgregor. With list of selected references.

Notes on the Geology of the Elie District. Supplied by G. A. Cumming.

Notes on the Old Red Sandstone and Glacial Deposits of Perthshire and Angus. Supplied by C. F. Davidson.

Era.	System and Subdivision.	Igneous Rocks.
Quaternary	Recent and Pleistocene: Blown Sand. Peat. Freshwater Alluvium. Marine Alluvium. Sand and Gravel. Boulder Clay.	
Tertiary	Period of erosion.	
Mesozoic	Absent, but Cretaceous sediments may have been deposited and subsequently eroded in Tertiary times.	
Upper Palaeozoic	*Permian.* Folding and Faulting in Permo-Carboniferous times.	Volcanic Necks. Quartz-dolerite dykes and sills.
	Carboniferous: Barren Red Coal Measures. Productive Coal Measures. Millstone Grit. Carboniferous Limestone Series. Calciferous Sandstone Series.	Volcanic Necks of uncertain age. Dolerite Sills. Lava and ash near Largo. Lavas, tuffs, and necks, Burntisland-Seafield.
	Old Red Sandstone: Upper Old Red Sandstone. Period of Folding and Erosion. Lower Old Red Sandstone.	Intrusions near Dundee and Leuchars. Lavas of Sidlaws, Ochils, etc.
	Junction with Highland Border Series Faulted.	
	Ordovician-Cambrian. Highland Border Series.	Lavas and Intrusions.
	Junction with Highland Schists Faulted.	
Pre-Cambrian ?	Highland Schists.	

III.

CLIMATE OF THE DUNDEE DISTRICT

BY

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In making a study of the " climate " of Dundee we find that certain factors operate to cause local differences within the City and to separate and relate the City to the District. The most noteworthy of these are :—

(*1*) *Site.*—The city stretches E. to W. along the north bank of the Tay estuary at its narrowest. Here a bridge and a ferry join the city to its " dormitories," Newport and Wormit, on the southern bank. West of the bridge there is virtually an inland sea, tidal, 2-3 miles wide, and surrounded by hills. The western districts of the city have protection against most of the winds except the prevalent one, the S.W., which sweeps down the Tay valley through the gap between the Sidlaws and the Ochils and Fife Hills. The eastern districts and the lower estuary, where are situated the docks, are slightly more sheltered from the S.W. wind, but are somewhat more exposed to the other winds ; to the east, on both sides of the river, the land sinks to sandy stretches facing the open sea.

(*2*) *Aspect.*—The city also lies on the fairly steep slopes of the ridge formed by the Law (572 feet) and Balgay Hill (362 feet). The greater part of the city thus has a southern aspect, but the northern districts are higher (300 feet or over) and face the north.

(*3*) *Distance from the Open Sea.*—The city lies about ten (10m.) miles inland, and backed by hills, has less sunshine and more rain than places actually on the seaboard. Nevertheless, Dundee lies within the sunny East Coast belt extending from Aberdeen to the Forth. The higher ground to the north outside the city boundaries, where are situated the city reservoirs, has a much heavier rainfall.

Detailed instrumental observations for Dundee (Mayfield)—147 feet—are available only since 1923. Readings for sixteen (16) years, up to and including 1938, are submitted. This gives about half the range of readings taken to furnish the " Normals " for the district. The Eastern Necropolis, where the 35 year series of readings were taken (1881-1915), differs little in height from the present station, and lies about 300-400 yards to the east. Apart from difference in the time of observations, some comparison is possible. Sunshine is measured on the roof of the Training College, in the centre of the city. Just outside the western boundary is Balruddery (276 feet), for which another set of " Normals " is available.

TABLE I.

DUNDEE (MAYFIELD), 1923-1938.

	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean Max.	43·8° F.	43·7	46·7	50·8	56·0	62·7	67·1	65·9	61·5	54·0	46·7	43·4	53·5
Mean Min.	34·8° F.	33·8	35·8	38·1	42·1	47·2	51·8	51·0	46·9	41·9	36·5	35·1	41·3
Mean T° Range	9·0° F.	9·9	10·9	12·7	13·9	15·5	15·3	14·9	14·6	12·1	10·2	8·3	12·2
Mid T°	38·8° F.	38·8	41·3	44·5	49·1	55·0	59·5	58·5	54·2	48·0	41·6	39·3	47·4
1884-1915	37·1° F.	37·5	39·8	44·1	49·4	55·4	58·4	57·3	53·5	46·7	41·3	37·6	46·5

DUNDEE.

The figures in Table I. would suggest that the period under review was warmer than the pre-war period (1881-1915). This is most marked in the winter months, December-March. The early summer months, April-June, may even be slightly cooler, and late summer, September, appears to be only slightly warmer. November figures are about the same in both periods, but an increase is revealed by the figures for the summer months of July and August—over one degree, 1° F., of a rise.

TABLE II.

LOWEST MIN. TEMP. AND HIGHEST MAX. TEMP. FOR EACH MONTH.

Lowest.			Highest.		Lowest.			Highest.	
1931	11° F.	Jan.	56° F.	1925 1932 1935	1935 1938	36° F.	July	86° F.	1933
1929	12° F.	Feb.	57° F.	1925 1935	1932	30° F.	Aug.	81° F.	1935
1931	13° F.	Mar.	68° F.	1929	1933	23° F.	Sept.	74° F.	1938
1928	19° F.	Apr.	70° F.	1937	1925 1930	19° F.	Oct.	67° F.	1927
1929	21° F.	May	72° F.	1934 1937	1930	15° F.	Nov.	61° F.	1933
1926 1936	29° F.	June	79° F.	1933 1938	1935	11° F.	Dec.	56° F.	1926 1931

Monthly Range Extremes 50° + or − 5° F.

The "mean" Range conceals an exceedingly wide range of extremes, as will be seen from Table II., which shows the recorded "limits" and the year of occurrence. In most years temperatures fall to 20° F. and under during the period December-March; and February usually has temperatures falling even below 18° F. On the other hand, during these months Day Temperatures will seldom fail to reach 50° F. The upper limit, 86° F., was touched on one single day, but during most years temperatures of 75° F. and over are recorded in June, rising to 78° F. in July; during this month 80° F. (and over) is not uncommon. In August the most common upper temperature is about 72° F., although 81° F. was recorded in 1935. In the summer months air temperatures falling below 32° F. are infrequent, although they are on record; but during June and August in most years temperatures will fall below 35° F. and below 40° F. in July.

TABLE III.

GROUND FROST.

AVERAGE OCCURRENCE (1923-1938) OF TEMPS. 30° F. AND BELOW ON GRASS.

January	17	July ..	—
February	15-16	August	?
March	14	September .	1-2 (16*th**) (earliest)
April	8-9	October ...	8
May	3-4 (21*st**) (latest)	November ...	14-15
June	1 in 5 years.	December ..	16-17

Table III. shows that Night Frost may occur in every month of the year, with the exception of July, although it is rare in June (once in every 5 years) and exceedingly rare in August (two nights in 1932—the only time in the period). To the gardener, the mid-week of May represents the end of the danger period, and planting out of the less hardy plants can be undertaken, e.g. Dahlias. In the higher and more northern districts it will be safer to allow another week to elapse. The earliest frosts may come about the 16th September, but plants seldom shrivel up before end of October; in most years in sheltered places there is little danger until the end of the month. Chrysanthemums are usually safe out of doors during all November, and Dahlias may remain in full bloom, in favourable years, until December.

WINDS.

Ground Frost happens most frequently during periods of relative calm, when wind velocities are of the order 2 or under. Usually there are clear skies overhead, and the waters of the estuary, particularly above the bridge, are without a ripple. Calms, however, especially during March-April and September-November, may be accompanied by mist over the water. Frost seldom occurs when the wind is from the East. The East wind is probably the most disagreeable of the winds, bringing cold and miserable weather, with persistent drizzle in the winter, and carrying a "haar" right up the river in spring and in summer. Although it may "feel" cold, it seldom brings temperatures below Freezing Point. The prevalent wind is the South-West, following the line of the valley. It frequently brings rain, and the approach of a downpour in the summer can be seen as a dark screen, stretching the whole width of the valley. The northern parts of the city experience, with little mitigation, the cold wintry blasts from the north.

Wind velocities are mainly of the order 3-4-5, varying, with position throughout the city, east or west, high or low. Wind velocities tend to rise somewhat towards the end of the year, and reach gale force most frequently in October, December, January, February. In November there is a lull.

TABLE IV.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1923-1938	35	22	9	6	2	7	1	3	18	23	9	33	168—16 yrs.
1930-1938	32	18	5	6	1	4	—	2	11	11	8	20	118— 9 yrs.

Since 1930 the frequency of gales seems to have increased, over 70% of the total falling within the latter half of the sixteen year period. One particular "observation" may be of interest, in that the piers of the first Tay Bridge still remain as evidence of the most destructive gale of 1879.

TABLE V.

RAINFALL IN INCHES.

DUNDEE (MAYFIELD).

	1923-1938.	Normals, 1888-1915.		1923-1938.	Normals, 1888-1915.
Jan.	2·47	1·95	July	3·2	2·74
Feb.	2·04	1·88	Aug.	3·14	3·28
Mar.	1·77	2·06	Sept.	2·81	2·08
Apr. ...	1·92	1·70	Oct.	3·48	2·66
May	2·41	2·09	Nov.	2·56	2·44
June	2·21	1·80	Dec.	2·50	2·66
			Year	30·51	27·44

RAINFALL AND SUNSHINE.

Table V., for the shorter period, also reveals changes in rainfall as compared with conditions during the "normal" period. Total precipitation has increased by slightly over three inches, the greatest increase falling in the months of September and October. A few months, March, August, and November, are actually drier. Details for the months during the period are found in the Appendix.

On the average, precipitation in some form, rain, hail, or snow, falls every second day, 184 days out of 365.

TABLE VI.

BRIGHT SUNSHINE (TRAINING COLLEGE ROOF).

	Length of Day.	Hours per Day.	Monthly.	Per cent.
January	7·50 hrs.	1·83	56·6	24
February . ..	9·43	2·66	74·5	28
March . .	11·75	3·38	104·8	29
April	14·14	4·4	132·0	31
May	16·31	5·13	159·1	31
June	17·53	6·12	183·6	34
July	16·98	4·87	151·1	28
August	15·07	4·82	149·5	32
September	12·75	4·06	121·9	32
October	10·37	3·24	100·5	31
November	8·16	2·17	65·1	27
December	6·87	1·36	42·1	20
Year	12·25	3·67	Total 1340	30

From the end of October until the beginning of the first week in March rain falls, on the average, 5 days in the week. This period coincides also with the period of minimum sunshine (see Table VI.), and includes the weeks of maximum precipitation, weeks commencing October the 29th—·68 in., and December 3rd—·78 in.

onwards. Potatoes are lifted in October; and the sowing of winter wheat usually completed by the end of November. Cultivation goes on throughout the winter months whenever there is open weather. The drying conditions of March and April allow harrowing for the preparation of the seed bed and the sowing to proceed. Spring wheat may be sown by early March; oats and barley in March and, at latest, mid-April. By the end of April potato planting will probably be over, and turnips will be sown in May. A hay crop will be taken in July. The warmth and rains of July and of August still encourage growth, but usually some of the harvesting has been started by mid-July, e.g. early wheat. The main wheat crop will be taken by mid-August. Shortly after this barley and oats should ripen sufficiently, and in the drier days of September cutting and leading-in of these should be completed.

In addition to readings taken at Mayfield, figures were supplied by the City Water Engineer's Department; Park Superintendent, Arbroath; and Burgh Surveyor, Carnoustie, and permission was granted by the Controller, H.M.S.O., to quote "normals" and "averages" compiled by the Meteorological Office.

IV.

THE FLORA OF THE DUNDEE DISTRICT

BY

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THE whole of Angus, the esturine region of the Tay known as the Carse of Gowrie with the extension of the Sidlaws into Perthshire, the North of Fife to the East Neuk—the Southern shore of the Firth of Tay, these are the limits set for the Dundee district. In this survey opportunity has been taken to call attention to the flora of the Esk basin, which belongs properly to Mearns. This favoured corner escaped notice in the Handbook of 1912 and only received passing reference in the Aberdeen Handbook of 1934.

It is from the ecological study that the best impression of the vegetation of any tract of country is obtained. In the ecological study of plants in this country first place must be allotted to the pioneer work of Robert Smith. In 1898 and 1901 " The Plant Associations of the Tay Basin " were published, and in 1904-1905 Parts III. and IV. of the Botanical Survey of Scotland dealing with Fife and Forfar were completed by William G. Smith on the notes left by his brother. Within the region under review the vegetation is grouped into four well marked botanical regions, viz., The Maritime Region, The Regions of Cultivation of Farmland, Woodland, and Moorland. These divisions correspond to those set out in 1813 by the Rev. J. Headrick in his " Survey of Angus," namely, the Coast, the Sidlaw Hills, the Valley of Strathmore, and " that portion of the Grampian Mountains which it (Angus) includes."

The maritime region with its irregular coast line shows a varied vegetation. Sandy shore with fringing sand dunes occurs at Montrose, Lunan Bay, Arbroath, Easthaven, Barry, Tentsmuir, St. Andrews, and Largo. This is interrupted by bold cliffs and rocks at St. Cyrus, from Montrose to Arbroath and along the Fife coast. Inland the sand dunes give place to grass dunes with golf courses at Montrose, Carnoustie, Monifieth, and St. Andrews, while grassy heath still persists at Barry and Tentsmuir. Mud flats with salt marsh plants occur in the tidal esturies of Montrose Basin, in the Tay at Invergowrie and Kingoodie, Balmerino and Tayport, and on the Eden from Guardbridge. The reputation of St. Cyrus as a botanical resort is based on the list of plants found on the calcareous material of the Upper Old Red Sandstone. These include Fumaria densiflora, Arabis hirsuta, Helianthemum chamaecistus, Viola hirta, Silene nutans, Hypericum perforatum, Trifolium striatum, Ononis repens, Astragulus danicus, Vicia lutea, Carlina acaulis, Campanula glomerata, Origanum vulgare, Phleum arenarium, Avena pratensis, Avena pubescens. Near Montrose Carex divisa and Koeleria arenaria occur together. A few of the more local or noteworthy plants recorded from North Fife are Silene anglica, Stellaria aquatica, Erodium maritimum, Vicia Orobus, Filago gallica, Malaxis paludosa, Corallorrhiza trifida, Goodyera repens, Juncus filiformis, Juncus subnodulosus, Sesleria coerulea.

At one period Fife and Angus were covered with forest extending up to the edge of a treeless region in the mountains. The area north of Strathmore still shows a more varied woodland than any other region, presenting as the elevation increases from the plain a passage from mixed deciduous wood up the main streams where oak becomes dominant. Above 900 feet the oak disappears leaving birch and rowan the dominant trees in the subalpine woods near the moorland. Seedlings of these trees are found up to 1,250 feet over Cairn O'Barns between Glen Clova and Glen Prosen. Coniferous wood occurs near sea level at Barry and Tentsmuir, at Montreatmont near Brechin, up to Balnagairn Wood near the head of Glen Clova, and the Larch and Scots Pine wood in Caenlochan in Glen Isla at 1,500-2,000 feet, the highest limit of woodland.

The region of cultivation has been introduced by man into the pre-existing vegetation of woodland. Nearly five-sixths of Fife is under cultivation, a larger proportion than any other county in Scotland; in Angus less than half the total area is farmland, while the Carse of Gowrie is renowned for its farming. Wheat is grown in the narrow coastal strip, in the Carse of Gowrie, portions of Strathmore reaching 400 feet, the lower southern slopes of the Sidlaws reaching 660 feet, and the Howe of Kinnaird. An upper zone of cultivation without wheat reaches the 1,000 foot contour.

One of the classical localities for plants in Angus is the chain of lochs and marshes on the Lunan. Rescobie and Balgavies, about 3 miles to the east of Forfar, attracted Don and Gardiner and at a later date Abram Sturrock and J. Knox. In addition to containing rare plants, the marshes round these lowland lochs contain many of the reed-swamp plants found in the Tay. Outstanding plants are Caltha radicans, Ranunculus aspergillifolius, and Lastraea (Dryopteris) thelypteris in the neighbouring marsh at Restennet, while in the Carse Oenanthe fistulosa, Cynoglossum officinale, and Catabrosa aquatica are local rarities.

The moorland region lies mainly on the hills and mountains above the region of cultivation and is divided into two groups by Strathmore. From Perth the Sidlaws bound the Carse of Gowrie on the north, and increasing in height to 1,399 feet on Auchterhouse form the southern rampart of Strathmore. The northern heights of the lowlands have steep, step-like slopes intersected by dens to the south-east and a long gentle slope to the north-west. Grass association or hill pasture cover the slopes of the andesite and sandstone hills of Perth, while heather clothes many of the summits, especially on the basalt-sandstone area to the north of Dundee, e.g. Gallow Hill, Craigowl, and Auchterhouse Hill, while, where the soil is poorly drained, peat may form but is nowhere extensive. Whin in distribution follows the andesitic hills and basalt outcrops and is abundant up to 600 feet, rising to 1,000 feet on Kinpurney. Above this is a well defined zone of bracken extending up to 1,500 feet in places.

In the parish of Lundie, near Newtyle, on the south side of the Sidlaws, are two small lochs only 1 mile apart. Abram Sturrock first called attention to the difference in the vegetation of these two lochs. The Round Loch lies in farm land with trees and undergrowth on the northern shore and the shore line is obscured with reed swamp. The Long Loch is treeless and is without fringing swamp and contains Lobelia, Subularia, and Isoetes. The difference between the two is remarkable and is due to the difference in supply

of mineral salts in the water. Lowland loch and marsh, grassy moor and oak wood are all abundantly supplied with available mineral salts, highland loch and bog, heather moor and pine wood represent vegetation with a meagre supply of available salts.

Strathmore to the north is bounded by the southern slopes of the great highland plateau of the Eastern Grampians rising to an average height of 3,000 feet, from which spurs lead down intersected by Glen Isla, Glen Prosen, Glen Clova, and Glen Esk. The moorland of the Grampians includes both subalpine and alpine forms of vegetation. Grassy foothills with associations similar to those of the Sidlaws are succeeded by heather moor coincident with the occurrence of mica schist and quartzite and quartzite schist. Above this is the upper hill pasture which may be looked upon as grass heath with admixture of mountain species or Vaccininium with a preponderance of lower range plants.

The arctic alpine region is clothed with grasses much mixed with blaeberry and little heather where the drainage is good or with poor heather mixed with blaeberry on deep peat in hollows. At the same time the geology of the plateau is favourable to the formation of moist and sheltered crags, particularly the mountains of Clova and Caenlochan whose wealth of rare species was first made known by George Don and later by William Gardiner. These characteristic arctic-alpine plants occur chiefly on the exposed cliffs below the plateau and this is the pilgrimage of each succeeding generation of botanists to visit Lychnis alpina, Astragalus alpinus, Oxytropis campestris, Erigeron alpinus, Saussurea alpina, Lactuca alpina, Gentiana nivalis, Bartsia alpina, Alopecurus alpinus, Phleum alpinum, Poa alpina, Carex Grahami, Carex Sadleri, Carex rariflora, Carex Halleri, Carex Lachenalii, Carex rupestris, Cystopteris montana, Woodsia ilvensia, Woodsia alpina, Athyrium flexile at home.

" The Flora of Forfarshire " published in 1849 by William Gardiner is the only Flora and the earliest record of the plants in the County, save Don's list of " Native plants in the County of Forfar " printed as an appendix to Headrick's " Agriculture of Angus or Forfarshire " (1812). H. C. Watson in " the New Botanist's Guide " (1837) gives a list of the rare plants to be found in Forfarshire. Edward Muir writing the chapter on Botany in Alex. J. Warden's " Angus or Forfarshire " enumerates " a few of the rarer and more interesting plants " ; a local list for Arbroath was published as " the Flora of Arbroath " in 1882, and there is the account of " the Flora of Forfarshire " by James Brebner in the Handbook for the Dundee Meeting (1912). The records for the Carse of Gowrie are to be found in " the Flora of Perthshire " by Dr. Buchanan White edited by Professor Trail (1898). Watson, in the Guide referred to, gives a list of rare plants of Perthshire and of Fifeshire, and " a list of the Flowering Plants and Ferns of Fife and Kinross " by William Young occupies the major portion of the centenary number of " the Transactions of the Botanical Society of Edinburgh " (1936), and from this the records of the North of Fife plants are obtainable.

Behind these larger works lies the organised and devoted efforts of the members of the Natural History Societies situated in the area. These workers laid the foundations of our knowledge of the flora, and it is very right and proper that tribute be paid to their excellent work and that the lasting debt be acknowledged. To take but one instance—in " the Flora of Perthshire "

568 plants are recorded for the botanical district of Perthshire called Gowrie, and so thoroughly had the work been done that only one additional plant to be found in Gowrie occurs in William Barclay's "Additions to the list of Perthshire plants" published in 1912, and not one reference to a Carse plant appears in Professor Mathews' "Recent Additions to the List of Perthshire plants" printed in 1927.

The names of the societies working within or adjacent to the area are given in geographical order along the coast, starting from the North, in the following list:—

Town.	Name of Society.	Dates.	Membership in 1889.
Montrose—	The Natural History and Antiquarian Society of Montrose	1836	100
	Montrose Scientific and Field Club	1882-1890	10
Arbroath—	Arbroath Horticultural and Natural History Society	1880-1905	68
	Arbroath Scientific and Natural History Society	1905-1936	
Dundee—	The Gleaners of Nature	1828-1835	
	The Dundee Naturalists' Association	1847-1849	
	The Dundee Naturalists' Society	1874	154
	The Dundee Naturalist Field Club	1868-1884	
	The Dundee Working Men's Field Club	1885-1910	20
Perth—	Perthshire Society of Natural Science	1867	260
Largo—	Largo Naturalists' Society	1863-1894	24
Kirkcaldy—	Kirkcaldy Naturalists' Society	1882	136
Dunfermline—	Dunfermline Naturalists' Society	1902	
Alloa—	Alloa Society of Natural History, Science, and Archaeology	1865	
Stirling—	Stirling Field Club	1878	93
	East of Scotland Union of Naturalists' Societies	1884-1894	785

Thus at one time or another there were 16 societies working in the pursuit of Natural Science; to-day there are but seven and of these, two persist in little more than name. In these days when the interior of the cinema and the motor car are preferred to the open country, but while the names of those who did so much for Natural Science are still remembered, it is most fitting to record the debt to their services.

Among the celebrated botanists connected with Angus two names stand out prominently from the rest: Robert Brown, who outstripped all his contemporaries in the extent and accuracy of his knowledge and in his comprehensive views of affinities in the vegetable kingdom, made some first records for his native county before he travelled forth; George Don, whose discoveries of new plants are larger and more important than those made by any other British botanist. Nor must we forget Lady Jane Carnegie, who compiled a herbarium between 1834-1840, gifted later to the Arbroath Society and now in University College, Dundee. William Gardiner, founder of "The Gleaners," is the author of "the Flora of Forfarshire" (1849). In it appear the names of many workers who supplied Gardiner with his stations, and among these names are included the Rev. J. S. Barty

of Ruthven; Archibald Bousie, gardener at Pitfour; Alexander Croall, a joiner, who became Curator of the Smith Institute at Stirling; J. Cruickshanks; the Rev. J. O. Haldane of Kingoldrum; John Laing, gardener at Kinnaird; A. Kerr, and G. M'Farlane. Professor George Lawson contributed papers on Forfar and Fife plants before he went to Canada. Later workers include James Brebner, John Knox, and Abram Sturrock. Nor were the flowerless plants neglected. Thomas Drummond, gardener at Invereighty, made the earliest contribution to the study of the mosses, to be followed by William Smith of Arbroath who worked with the Rev. John Ferguson of Fearn, author of a "List of Forfarshire Mosses," and later John Fulton, a jute worker, who wrote the article on "the Mosses of Forfarshire" for the 1912 Handbook. The Rev. John Stevenson of Glamis published his "Mycologia Scotia" in 1879, and the marine algae are in the safe hands of James Jack, Arbroath. To these should be added the names of Professor Sir Patrick Geddes, Robert Smith, pioneer in ecology, Marcel Hardy who extended his work, and George West associated with the Scottish Lake Survey, all of whom were associated with the Botany Department, University College, Dundee.

The earliest account of the Carse is in "the Flowering Plants of the Carse of Gowrie" by Colonel H. M. Drummond Hay (1874), and there are numerous papers by William Barclay and Robert Dow, Longforgan, in "the Transactions of the Perthshire Society of Natural Science." R. H. Meldrum specialised on the Carse mosses, publishing a "Preliminary List of Perthshire Mosses" in 1898. Dr. Buchanan White published a "Preliminary List of Perthshire Fungi" in 1880, and Charles M'Intosh of Inver and James Menzies also worked with these plants.

The first list of Fife plants is by the Rev. John Anderson of Newburgh and appears as an appendix to "Fife Illustrated" by John M. Leighton (1840). George Lawson published a "List of Rarer Flowering Plants observed in Fifeshire in 1846-47" in the Phytologist (1848). Charles Howie, author of "the Moss Flora of Fife and Kinross" (1889), provided a list of plants for "The Shores of Fife" by W. Ballingall (1872). The Rev. Walter Wood in "The East Neuk of Fife" (1876) and Dr. Alex. Laing in "Lindores Abbey and the Burgh of Newburgh" (1876) give local lists of flowering plants. The Rev. Mark Anderson of the Town Church, St. Andrews, gathered numerous Fungi and G. W. Trail made a collection of the main Algae. Dr. John Wilson, first lecturer in Botany, and Professor R. A. Robertson did valuable work within the University. John Smith, born at Aberdour in 1798, was educated at Pittenweem and for 30 years held the post of Curator of the Royal Botanic Gardens, Kew.

One other name calls for mention, that of Professor James William Helenus Trail of Aberdeen. Throughout the records his name constantly appears assisting and encouraging the local workers.

V.

ANIMAL LIFE IN THE DUNDEE DISTRICT

BY

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On our local fauna no comprehensive work as yet exists, and this article can present but an outline of its outstanding features gathered from many scattered references. For those interested, however, the sources of detailed information are available in bibliographical and species indexes, and in collections of specimens, lodged in the Natural History Department, University College, Dundee.

HISTORICAL.

Earlier Literature. Our earliest source book is a little volume, "The County of Angus," published in 1678 by Robert Edward, Minister of Murroes (1), which contains scattered bits of zoological information. The next work, "General View of the Agriculture of the County of Angus, or Forfarshire," by James Headrick, Minister of Dunichen, is an important source book (2) for it deals with fisheries, native animals, farm stock, etc., and also includes a valuable appendix, "Account of the Native Plants in the County of Forfar, and the Animals to be found there," by that fine naturalist, George Don of Forfar. The third book, "A Fauna of the Tay Basin and Strathmore," by J. A. Harvie-Brown (3) contains many references, to vertebrates and birds especially. The fourth volume is the British Association's "Hand-book and Guide to Dundee and District" (4) with its articles on fisheries, whaling, fossils, birds, and on celebrated local naturalists.

The Earlier Naturalists. Patrick Blair (1666 ?-1728) was a Dundee "Surgeon-Apothecary" and Fellow of the Royal Society. Though primarily a botanist, he is of interest to zoologists because he was the first in Britain to dissect an elephant. The specimen, belonging to a travelling show, died at Broughty Ferry in 1706, and Blair's accurate paper on it, *Osteographia Elephantina*, was published in the "Philosophical Transactions of the Royal Society of London," 1710-12. His life, which he nearly forfeited through his adventure with the Jacobite Rising in 1715, has been well told by A. P. Stevenson (4).

George Don (1764 ?-1814), the son of humble parents, was also primarily a botanist. His life of many vicissitudes, traceable mostly to his craving for pursuing untrammelled his love of natural history, has been feelingly recorded by G. C. Druce (4). Don's faunistic contribution to Headrick's book (2) is remarkable and throws interesting side-lights on former local faunistic conditions. It comprises some 810 species, classified on the Linnaean system: 72 zoophytes (coelenterates, sponges, polyzoans and "infusoria"); 26 mammals; 166 birds; 30 amphibia (true amphibia, reptiles, and certain

fishes) ; 64 fishes ; 406 insects (true insects, crustacea, millipedes, centipedes) ; and 46 worms (nematodes, flatworms, annelids, molluscs, ascidians, sea anemones, echinoderms). Regarding mammals the pine martin, polecat, and stoat were rare, the badger " rather rare," the weasel " not unfrequent," and the hedgehog " formerly rare—but of late years it has appeared in tolerable plenty." The black rat was the only species in the town of Forfar, and not rare in inland parts, while the brown rat was common in the seaports. The rabbit was rare, " perhaps hardly a native." The red, fallow, and roe deer were all rare. Regarding birds, Don records the " erne " ; of eagles the sea, golden, ring-tailed, and black ; the kite ; the common honey and moor buzzards ; the gosshawk ; the gentle falcon ; the hobby ; the raven, jackdaw and Cornish chough ; the blackcock was rare, the ptarmigan occurred at Clova, and the red grouse was " becoming very rare of late years " and was threatened with extinction. As well as the common toad and frog, there was the edible frog " about the lakes, but rather rare," and " the grand frog of Lightfoot," three times the size of the common frog and possibly a rare native of the salt marshes.

Patrick Matthew (1790-1874), of Gourdiehill in the Carse of Gowrie, was an interesting personality. His book, " Naval Timber," 1831, contained a remarkable but completely undeveloped suggestion anticipating by over twenty years Charles Darwin's highly developed hypothesis of natural selection. One characteristic passage illustrates Matthew's conception : " As the field of existence is limited and preoccupied it is only the hardier, more robust, better-suited-to-circumstance individuals who are able to struggle forward to maturity . . . the weaker, less circumstance-suited, being prematurely destroyed " (see W. T. Calman, 4 ; and L. Melville, 5).

Charles Lyell (1797-1875) of Kinnordy, one of the greatest figures in the heroic age of geology, is remembered by zoologists for his influence on palaeontological studies (see p. 32).

John Hood (1831-1914) was by trade a turner in Dundee, but by nature was a naturalist. Concerning his career we cannot do better than quote Dr. William T. Calman (6). " Mr John Hood . . . was well known to many zoologists and microscopists as a collector of the more minute forms of fresh-water life and especially the Rotifera. The study of these attractive little animals was the hobby of his life, and though he published little under his own name, he gave very important assistance to many other workers. . . . He was especially successful in obtaining new and curious forms of the sessile Rotifera forming the group Rhizota. . . . His skill is shown by his making his own microscope. In his later years . . . he was in straitened circumstances, and sometimes perilously near actual privation. Only a year ago a small pension from the Murdoch Trust . . . brought ease of mind and some comfort to his last days. Probably very few of his numerous correspondents knew him personally, but those who did know that he represented a particularly fine type of the ' working-man naturalist,' a type . . . . which was more characteristic of the nineteenth century than it promises to be of the twentieth." He was a Fellow of the Royal Microscopical Society for 33 years, and his only major paper, " On the Rotifera of the County Mayo " (7), written, as he says, " under the guidance of Professor D'Arcy Thompson," deals with about 220 species (see also p. 46). His photograph, showing him bearded and wearing a black skull cap, reminds one strongly of Darwin.

Local Institutions. The Central Museum and Art Galleries of Dundee house Arctic animals, including two fine musk-ox, all obtained from former Dundee whaling skippers, and the skeleton of a hump-backed whale, *Megaptera longimana* (Rudolphi), the "Tay Whale," fatally wounded in the Tay, Jan. 1, 1884, and finally taken off Kincardineshire (White, 8). There is also a fine assemblage of local fossil fishes collected by Lord Kinnaird last century. The Dundee Naturalists' Society possess a small representative collection of local birds and are also the fortunate owners of some remarkable local fossils, including the giant primitive arachnid, *Pterygotus anglicus*, and certain primitive fishes (see p. 33). The Natural History Department of University College, Dundee, was founded by Professor D'Arcy W. Thompson and directed by him for over thirty years. Its general museum, including extensive named collections of most invertebrate groups, is his work, and its most notable trophy, a skeleton of Steller's sea-cow, *Rhytina stelleri*, was brought by him from Behring Island in 1898. Of his many activities in Dundee mention may be made of his long-continued researches on fisheries, and of the publication of his notable work "On Growth and Form" (9). The short tenure of his successor, Professor J. F. Gemmill, was marked by work on the wheat bulb fly (p. 45). Since Professor Gemmill's death the main researches in the department, under Professor Peacock, have related to the biology and cytology of animal parthenogenesis, and, recently, progress has been made in a local faunistic survey, towards which end a Field Station has been established at Glen Doll, Angus. The Art Gallery and Museum, Perth, is the headquarters of the Perthshire Society of Natural Science and houses the Society's well-displayed representative collections of the fauna, flora and petrology of Perthshire.

Whaling. Dundee was long recognised as one of the main centres for Arctic whaling and sealing, but these characteristic activities ceased in the Spring of 1914, when the last northern voyage was made by two whalers. Whale and seal oils were formerly much in demand as illuminants, and are still used locally for processing jute. High (4) states that whereas in 1867 the number of vessels engaged was twelve, representing a capital estimated at £200,000, the number in 1912 had fallen to eight, only two of which had made the northern venture that season. The decline of the industry was primarily due to the ruthless and uncontrolled slaughter of the Arctic whales and seals by the whalers of several nations, which brought about the extreme scarcity of the animals. One would have thought that, faced with failure in the north, the Dundee whaling business would have made a bid for a share in the prosperity of the Antarctic fishings. This, however, was never done, whether through lack of enterprise, or because local capital found greater profit elsewhere, it is difficult to say.

The Fauna of the Past.

The Palaeontological Features are of more than local interest, for the red sandstone fossils have afforded invaluable material for studies in the evolution of fishes and vertebrates since they excited the attention of such bygone eminent geologists as Roderick Murchison, Dean Buckland, Charles Lyell, Hugh Miller, and Louis Agassiz, the great Swiss naturalist. Some aspects of this history have been admirably recorded by the late James B. Corr (10, 12).

Certain very remarkable and enigmatic fossils from the Lower Old Red Sandstone of Balruddery and Carmyllie, Angus, and of Wormit Bay, Fife, were known to the Forfarshire quarrymen as "Seraphim," because of the resemblance of their elliptical scale-like markings to the wings of cherubs. Fragmentary remains were of frequent occurrence at Balruddery, and up to the time of Agassiz's visit to the Den no geologist had ventured to offer an opinion on them. Hugh Miller (11) relates how the great Swiss naturalist examined a group of dislocated fragments in the presence of Charles Lyell and other eminent geologists; how, as his eyes brightened, he said, "I will tell you what these are,—the remains of a huge lobster"; and how he arranged the fragments so that the general outline of an entirely new crustacean gradually dawned upon his admiring friends. This animal, *Pterygotus anglicus*, however, is not a crustacean, but an eurypterid, a primitive arachnid, the modern forms of which include the scorpions and spiders. The Dundee Naturalists' Society, as well as possessing fragments of this type, has a magnificent specimen, over five feet long, from Carmyllie, and also a fine specimen of a closely related form, *Stylonurus*, apparently undescribed and probably well worth an expert's consideration.

In a quarry near Glamis a workman discovered the first local fossil "pre-fish". It was sent to Lyell at his home at Kinnordy, who, in turn, sent it to Agassiz in Switzerland. Agassiz named and figured the specimen as *Cephalaspis Lyelli*; it is now in the British Museum collection. This creature is now regarded as a primitive vertebrate, jawless, with a fish-like body, and a large head covered by a large bony shield. The same form was found in the Balruddery rocks.

Fossils of fish-like forms higher than Cephalaspis have been found in the Upper Old Red Sandstone of Dura Den, Fife. From their size and peculiar appearance, they were originally supposed to be beetles. The creature, called *Bothriolepis hydrophila*, was "essentially an elongate oval bony box, about 3 or 4 inches in length with a pair of long paddles movably articulated with its sides" (Woodward, 4).

Still higher forms, and definitely fish, are several species of "presharks," Acanthodia, from the Lower Old Red Sandstone at Farnell near Montrose, Turin Hill near Forfar, Carmyllie near Arbroath, Balruddery Den near Dundee, and on the Tay at Wormit Bay, Fife. The name refers to the characteristic large front spines supporting all the fins except that of the tail, a feature which sharply separates them from all other fishes. They are the most archaic and earliest of jawed vertebrates. The most successful of local workers in the group was James Powrie of Reswallie, "whose extensive collection of local specimens, unrivalled for the beauty and rarity of the specimens, is now permanently located in our National Museum at Edinburgh" (Corr, 12). Much of Powrie's material came from Turin Hill and the Dundee Naturalists' Society possesses certain specimens given by Powrie himself. Powrie's and the Society's specimens are re-described by Professor D. M. S. Watson in his recent authoritative monograph (13), from which we note that one of the Society's specimens is of particular interest because it elucidates the structure of the nostril.

Belonging to another evolutionary line is *Holoptychius nobilissimus*, definitely a fish and found in the Upper Old Red Sandstone at Clashbenny Quarry. Here was obtained the type specimen, now in the British Museum,

as well as other species described by Agassiz. These fishes are of the fringed-finned group (Crossopterygia), had heads heavily armoured with thick bony plates, and belong somewhere near those forms which gave rise to the earliest lung-breathing fishes, from which sprang later kinds of lung-breathing fishes, as well as primitive amphibians that were becoming adapted to land life.

The yellow sandstone of Dura Den, Fifeshire, also yielded species of holoptychians and other crossopterygians, and a species of lung-fish, *Phaneropleuron Andersoni*. The number of species of fishes and the abundance of individuals found at Dura Den give evidence of some catastrophe overwhelming them in shoals, but the nature of the catastrophe is not known. (See Craig and Balsillie, 4.) Additional interest is attached to these crossopterygian fossils because of the recent capture, off the coast of Africa, of a "living fossil" relative, five feet long, belonging to the coelacanths, a group hitherto supposed to have become extinct some 50 million years ago (Smith, 14).

That the Tay fauna was once comparable to that now existing in the Arctic of West Greenland is shown from the remains of shells, crustacea, starfish, mammals, etc., found in the clays and sands associated with the deposits of the raised beaches, terraces or platforms, considered to mark pauses in the uplift of the land since the Ice Age. The local deposits of glacial origin are principally those laid down during the last stages of the melting and retreat of the ice (Balsillie and Craig, 4; C. F. Davidson, 15). The skeleton of the north Atlantic ringed seal (*Phoca hispida*) was found in the clays of the 100-foot terrace at Cupar Muir; the humerus of the same species, as well as numerous specimens of a starfish, *Ophiolepis gracilis*, in the clay at Seafield; and certain molluscan shells, such as *Yoldia arctica*, *Pecten groenlandicus*, *Tellina calcarea*, and *Thracia myopsis*, in the clays of Errol, Barry and Arbroath. In the 50-foot terrace at Polgavie and at Inchture in the Carse of Gowrie numerous specimens of *Scrobicularia piperata* have been obtained.

The Arctic clay of Inchcoonans, Errol, provided the finest fauna of its kind in the East Coast (Davidson, 15). It comprises 22 species of mollusca, including the edible oyster, a mussel, and 2 species of rock-borers; 22 species of lower crustacea (Entomostraca), with *Cythere mirabilis* as the dominant form, and one barnacle; 1 species each of starfish, worms, and polyzoa; 4 species of foraminifera; and one mammal, the common seal. The fossils, e.g., oyster, found in the uppermost beds were distinctly less Arctic species, indicating that conditions were gradually becoming warmer, for the oyster to-day does not extend north of the Arctic Circle.

The flora and fauna of the higher deposits of peat and estuarine clay are those of to-day.

The presence of horses at an early age in the development of Scotland is attested by remains found in different part of the country, including the Angus marl mosses (Lyell, cited by J. Ritchie, 16). The remains are those of a small horse, called by Ewart the "plateau type" (*Equus agilis*), which roamed the plains of Italy and France. It must have resembled the modern Iceland pony, which itself is characteristically Ewart's Celtic pony (*Equus agilis celticus*). The presumptive evidence is strong that this small horse was one of the domesticated animals of neolithic man in Scotland, which he reached after the Glacial Age, but it is uncertain whether the Scottish relics pertain to animals which came in the train of the post-glacial neolithic

colonizers or to animals which certainly lived in Scotland before the advent of these colonists.

Animals More Recently Extinct. Of the giant wild ox of Europe, the aurochs (*Bos primigenius*), a horn core and skull fragment were found at Mugdrum, in north Fife (John Ritchie, 17); and of the "Irish" elk (*Alces alces*) remains have been obtained in the Angus marl beds. This latter animal almost certainly persisted in Scotland beyond the ninth century, its extinction being most probably due to the destruction of the forests, its natural haunts, a destruction begun by the Romans (James Ritchie, 16).

Animals Recently Extinct. The last killing of the wolf in Angus occurred about 1680, but the species probably lingered until 1743 in wilder regions of Scotland (James Ritchie, 16). The pine marten was regarded as rare by Don in 1813; he records one as being shot in 1808 near Glamis. The last record is dated 1860 (James Ritchie, 16). The polecat or foumart was also mentioned as an Angus rarity in 1813 by Don, but it was common in the Tay basin in 1820 and became extinct before 1882, according to Drummond-Hay (see Harvie-Brown, 3). It still lingers in the wilder northern highlands of Scotland. The extinction of both these has come about by their being victims of the fur trade in earlier times, and, with the spread of agriculture, by being classed as vermin (James Ritchie, 16). The badger was abundant in the Tay basin about 1820-1824 but evidently became extinct towards the close of the same century (Drummond-Hay, see Harvie-Brown, 3). The black rat, the plague carrier, in Don's day, was the only rat known in Forfar as late as 1813, but whether it still persists inland is unknown, though occasionally fugitive specimens from ships are caught at Dundee docks.

Mammals.

Aberdeen-Angus Cattle. This breed of cattle from Aberdeen, Angus, and the adjoining counties is characterised by hornlessness, an almost uniformly black colour, and such a marvellous quality of flesh that it is doubtful whether any other beef is its equal. The animals are known as "humlies," or, more locally, as "Angus doddies." The origin of the polled condition and colour is obscure, though black cattle without horns have been known since the middle of the sixteenth century. The genetics of the breed have not been determined and any such study would be difficult because in both ancient and modern times crossings with other breeds have been made. So long ago as 1813 Headrick (2) remarked that the great proportion of permanent stock were "humlies," but that the county possessed various breeds of cattle of differing qualities, and that little attention was paid to selection. However, at the beginning of the nineteenth century the breed was greatly improved by Hugh Watson of Keillor, Angus, who followed the intensive inbreeding and selective methods of the great English farmer Bakewell. "While, perhaps, collectively the greatest part of the early work of improving the breed was carried out by Forfarshire breeders, individually they were all eclipsed by William M'Combie of Tillyburn, Aberdeenshire, who did more than any other person to secure for the breed its world-wide reputation" (Wallace and Watson, 18). The word "humlie" refers to the polled condition,—Anglo-Saxon "hamelian," to mutilate. The term "doddie," it is here suggested, may derive from a local place-name, for the Loch of Dodd is the old name for Rescobie Loch.

Silver Fox Farming. Mr J. M. D. Mackenzie, Sidlaw Fox Farm, Balbeggie, Perthshire, has kindly furnished the following information. There are a number of silver fox farms near Dundee and Perth, the dry cold climate of the East Coast suiting the animals and white hare and venison being readily available as food. Careful selection of the strain and good management have resulted in considerable success in show competitions. The silver fox is a melanistic mutant of the ordinary Canadian red fox, *Vulpes fulva*, the blackness being recessive to red. Little is known of the inheritance of fur characteristics, except that it seems to be possible that blackness and maleness, and paleness and femaleness, are linked. Husbandry has shown that the best diet must contain a certain amount of vegetable matter ; and that the incidence of internal parasites (except the bladder worm) is diminished by rearing in pens provided with board floors instead of earthen.

Deer. Red deer (*Cervus elaphus*) are still plentiful on the mountain moors and are hunted for sport. In winter they come down for food into the valleys in scores and even hundreds, and are a pest to the farmer. The roe deer is rare but was common on the Sidlaws in 1813 (Harvie-Brown, 3). The red, fallow and roe deer were stated to be rare by Don in 1813.

Other Mammals. The present local status of many of the common wild mammals remains to be determined. Of marine forms the common seal is still common, principally on the sandbanks near Tayport, and whales occasionally appear (see page 49). Of carnivores the weasel, stoat and otter occur, while foxes can be so numerous in the glens as to be pests. The rodents, at least in the Carse area (Harvie-Brown, 3), comprise wood mouse; house mouse ; brown rat ; water vole, the black variety, common around Perth ; field vole ; bank vole. The squirrel was not mentioned by Don in 1813, but was first seen in the Carse in 1822, probably arriving from Dunkeld, though the Tay has been colonized from both Clyde and Forth. The rabbit, of course, is too plentiful. Don in 1813 noted it as rare, " hardly a native," but Edwards in 1678 stated that it was in plenty in many places and that " their warrens when well stocked, are let at a very high price." Brown hares are common in the lowlands. The mountain hare of the higher levels is so abundant as to be a pest, three hares, it is said, eating the equivalent of one sheep. In the shooting season, November to February, as many as a thousand may be shot at a big drive. Of the insectivores, moles and hedgehogs are common—but regarding shrews there is no information. Of the bats Harvie-Brown (3) in 1906 records the long-eared bat in the Carse, and the pipistrelle and Daubenton's bat as common around Perth. Bats occur elsewhere but the species are not recorded.

Birds.

The status of the Angus birds is yet to be worked out. Baxter and Rintoul (19) list about 393 species for Scotland, 114 being resident ; the corresponding numbers for Angus are about 225 and 86. The subject is too detailed for treatment here, but the following deserve brief mention. The resident species are : coastal and aquatic—21 (see below) ; finches—12 ; birds of prey—8, peregrine falcon, merlin, kestrel, golden eagle, sparrow hawk, long-eared owl, tawny owl, barn owl ; game birds—5, grouse, blackcock, pheasant, partridge, capercaillie ; " crows "—7, raven, hooded crow, carrion crow, rook, jackdaw, magpie, jay ; pigeons—3, rock dove, stock dove, wood pigeon.

The Estuarine Birds. The estuarine region of great ornithological interest extends from the mouth of the Earn to Buddon Ness, about 24 miles, the main bird haunts being the reed and mud flats near Invergowrie, the extensive sandbanks exposed at low tide, and, at the mouth, the moorland and sandhills of Barry on the north and Tentsmuir on the south.

Records have been made by Hay (20), J. B. Corr (4), and W. F. Alexander (21), the species numbering about 76, of which 22 are resident, 6 are regular summer migrants, 23 are regular winter migrants, 17 are occasional winter visitors, and 8 are rarities from the Arctic. The resident birds are 9 waders and 13 swimmers: the waders are heron, lapwing, golden plover, oyster catcher, curlew, redshank, dunlin, and common snipe; the swimmers are shelduck, wild duck, teal, eider duck — all fairly common, the eider nesting on Tentsmuir, razorbill, common guillemot, cormorant, great black-backed gull, lesser black-backed gull, herring gull, common gull, kittiwake, black-headed gull. The regular summer migrants are 1 wader, the sandpiper; and 5 swimmers, the common, Arctic, lesser, and Sandwich terns, and the gannet. All except the gannet nest on Tentsmuir, arrive in May, the nesting colonies of the terns in early June being a wonderful sight. The regular winter migrants are 6 waders and 17 swimmers: the waders are greenshank, water rail, spotted crake (shy, retiring and uncommon), godwit, knot, and jack snipe, most of which are found on the mud banks during autumn and winter; the swimmers are 5 kinds of geese—grey lag, bean, pink-footed, white-fronted and brent (the bean and white-fronted becoming rare), and 8 kinds of duck—pochard, tufted, widgeon, scaup, common scoter, velvet scoter, golden eye, and long-tailed, as well as goosander and red-breasted merganser, both of which breed on lochs of the Tay basin, and the red-throated and black-throated divers, the latter being rare. The occasional winter visitors are 5 waders and 12 swimmers: the former are the bittern—rare, whimbrel—a passing migrant only, sanderling, turnstone, great snipe; the swimmers are wild swan, Bewick's swan, shoveller, pintail duck, smew, great-crested grebe, horned grebe, black guillemot, puffin—in autumn and spring, fulmar petrel, storm petrel, shag. The still more casual visitors from the Arctic, alighting on their north-south line of migration and seeking food during severe winters, are king duck, little auk—which occasionally invades in numbers, glaucous gull, Iceland gull, the pomatorhine, Richardson's and Buffon's skuas, and great northern diver—almost to be considered a regular winter visitor.

Cliff Birds. Regarding mainly the Arbroath cliff birds, Dr. Dewar of Arbroath has kindly summarized for us the fruits of a life-time of keen bird-watching. The peregrine falcon has bred at Red Head for sixty years at least. The kestrel is still seen now and again, but was common till after the Great War. The raven used to breed at Red Head, circa 1852. The hooded crow formerly nested on the Arbroath cliffs where it seemed to be resident. The rock pipit is common all along the shore. The rock dove nests in caves in the cliffs between Arbroath and Red Head, often mixed with domesticated pigeons. The oyster catcher is common all along the shore in winter and has been found nesting on the shingle banks of the North Esk. The greater ringed plover, the curlew, the redshank, the dunlin, and the purple sandpiper haunt the sands in winter, and the Arctic(?) tern, lesser tern, black-headed gull, great black-headed gull, and herring gull are also seen. The puffin

nests in various caves between Auchmithie and Red Head. The razorbill is common in winter time. The common guillemot nests near Auchmithie. The fulmar petrel has increased steadily in numbers during the past twenty years and is thought to breed. The gannet and the cormorant have been observed, the latter roosting on the Scart Rock, near Red Head, though nests have not been detected.

The sex ratios of the Tay ducks have been studied by H. Boase (22), who finds, broadly speaking, three possible variations: equality is shown in the mallard; apparent surplus of females in the widgeon, scaup and goosander; and a varying surplus of males in the shoveller, pintail, pochard, tufted duck, goldeneye, long-tailed, eider, scoter, velvet scoter, merganser.

Capercaillie. This handsome bird is still found in Angus, though its present status is not known. Dr. Dewar informs us that it is not uncommon on Montreathmont Muir, where nests have been found by him; and as recently as 1894 a bag of 107 was obtained at Fotheringham (James Ritchie, 16). The present denizens of the county, however, are descended from introduced birds and are not of native stock, which, with the destruction of woodlands, disappeared in Scotland about 1770. Edward (1) speaks of their local occurrence in 1678. The successful re-introduction of the bird was largely due to the Marquis of Breadalbane, who obtained specimens from the continent and freed them at Taymouth Castle, Perthshire, whence they spread along the Grampian system and elsewhere, reaching Glamis in 1863 and Brechin in 1870. Their success was augmented by stock introduced in 1862 at Cortachy by the Earl of Airlie. Its hold will depend upon the maintenance of the woodlands.

Courtship and Nesting Habits. Interesting observations have been recorded by that excellent observer, Mr Henry Boase (23), for fulmar, golden-eye duck, great crested grebe, and by Colman and Boase (24) for red-breasted merganser; eider, teal, and tufted duck (25); pied wagtail (22) and mallard (26); and sheld-duck (27, 28).

Migration. The westerly flight of swallows, house martins, sand martins, swift, finches, pied wagtail, missel thrush and skylark has been discussed by Boase (22). From fourteen years' careful observations with Balgay Hill, Dundee, as the central locality, Boase (29) also deals with the local movements, or "drift" incident to the migration of summer visiting birds. The birds principally concerned were willow-warbler, spotted fly-catcher, tree-pipit, redstart, blue tit, great tit, coal tit, goldcrest, and tree-creeper. While the actual direction of the main movement over the passage line on which Balgay Hill must lie has not been determined, there is some indication that it is south-east. However, the period of the main movement for the departure of the summer visitors has been determined as August 5-12, though movement is well on the way by mid-July and is almost completed by the first week in September.

The Spring migration along the valleys of the Tay and the Earn was observed by J. Berry (30), the records relating to sand martin, house martin, swift, swallow, chaffinch, common bunting, fieldfare, common sandpiper, and willow, grasshopper, and sedge warblers, and, especially, geese and ducks. That season on the Tay was very unusual as the weather conditions caused the birds to collect and move in great flocks, instead of allowing successively arriving smaller flocks to nest a short time and then hasten on.

The geese observed were pinkfoot, greylag, widgeon, bean, yellow-billed bean, and white-fronted, and Berry was greatly struck by the amazing numbers, especially of the pinkfoot and the greylag. The ducks were mallard, teal, widgeon, shelduck, and tufted—in large numbers, and goldeneye—in surprising numbers. Snipe, curlew, and redshank were also observed. The general line of geese migration from south to north was by Glenfarg, across the Tay near the mouth of the Earn, and north-eastward to cross the Sidlaws to the east of Dunsinane Hill. As for the duck the author (*in litt.*) considers it possible that they follow the coast northwards via Montrose and Aberdeen. The author also informs us that the pinkfooted and greylag geese seem to come from Iceland and the duck mostly from Scandinavia.

Fish.

Sea Fisheries. Interesting glimpses of local conditions early in the nineteenth century may be seen in Headrick (2). "In the sea are caught podlies (which seem to be the fry of the cole-fish), whitings, haddocks, cod, ling, and various others. It is only since stake-nets began to be erected in the Frith of Tay, that herrings were discovered in the frith, from some that were entangled in the nets. Since that discovery was made, considerable quantities of them have been occasionally caught in the Frith of Tay, during the winter season. But they are then very lean, and seem to be in the act, or about to deposit their spawn. Of late years, the herring-fishery has been tried in the open sea, . . . and considerable quantities taken in the months of June, July and August. Those earliest taken were plump and fat, and no way inferior to the best Lochfine herrings. . . . . Another discovery has been made by these stake-nets,—that garvies (sprats) and spirlings (smelts) abound in the Frith of Tay. . . ."

"Of flat fish, flounders of various kinds, soles, skates, thornbacks, and turbots abound in the seas; but as the fishers seem to be unacquainted with the use of trawl-nets, few are taken, except such as bite the bait used for cod or ling. Of the shell-fishes, there are several muscle beds, which are used for food when in season; but are generally used as bait for other fishes. The Dutch, who are dexterous fishers, always use eels, when they can be procured, as bait for cod and ling; and it would perhaps be advisable, that our sea-fishers should have recourse to the eels, which abound in some of our fresh-water streams, for these purposes."

"The sea near the Bell Rock, so long the terror of navigators, is said to abound with cod, ling, haddocks, and fish of all sorts; and this may be approached with safety now that a lighthouse is constructed upon it. The best fish are caught on banks, well-known to the fishermen, at a considerable distance from the coast. This business has been rather languid for some time past, because the young men are afraid of being impressed on board a man of war, should they venture out; and the old men are not able to go to a sufficient distance from the coast."

"Salmon fisheries have been carried out to a very great extent, on all eastern rivers and coasts of Scotland, ever since Mr Dempster of Dunichen suggested the plan of conveying fresh salmon to the capital of the empire, packed in ice. . . . Every salmon fishery of any note, on the east coast or rivers, is now provided with an ice-house, in which a sufficient stock of ice is stored during the winter, to serve during the ensuing fishing season."

"In the sea too they (salmon) grow rapidly, and soon get fat; and their gills, backs, and sides become thickly studded with a small black animal named by the fishers, the sea louse; whose attacks seem to inflict upon the poor salmon excruciating tortures, and force it to have recourse, for relief, to the fresh water. A few gulps of river water seem either to kill the sea louse, or to deaden the pain it inflicts."

Writing in 1912, the late Sir William High (4), from his personal business experience, deplored the fact that Dundee was not an important fishing centre despite its being the only suitable port between Aberdeen and Shields and within striking distance of grounds not fished by the drifters of Aberdeen on the north and those of Lowestoft and Yarmouth on the south. Success, he stressed, would depend upon dependable supplies of fish in large quantity, these, in turn, depending upon the operation of a large local fleet—from 40 to 50 trawlers for a start—a matter which would require a fair amount of capital.

For a recent review we are indebted to Dr. Henry Williamson, who writes as follows: "During the past fifty years a change has taken place in the fishery on the coast of Angus. Ports which once were active fishing centres have now abandoned fishing. This change has coincided with a decline in line-fishing, and the adoption of net-fishing. Montrose and Broughty Ferry, which are favourably situated in that they have adjacent beds of mussels, and sandy beaches where worm bait can be obtained, have now given up line-fishing and have reduced their operations to a very considerable extent. Arbroath, the only port where fishing, apart from steam-trawling, is carried on actively, has adopted the seine-net as the principal method of fishing for plaice or haddocks, while for herrings the ring-net is substituted for the drift-net. At Broughty Ferry, where at one time forty-five sailboats, measuring 15-60 feet on the keel, operated in St. Andrews Bay, Carnoustie Bay, on the Bell Rock ground and to the eastward of that region, there is to-day no fishing boat. These grounds provided plaice, dabs, haddocks, and cod, and lines were baited with lug, rigger, and mussel. At one time flat fish were also to be caught inside the estuary, but the fishing as a whole was carried on outside. Herrings are obtained here in autumn and winter, but in very uncertain quantities, their visits in large numbers being intermittent. Montrose used to be the most important fishing town in Angus. In addition to the line-fishing, a fleet of sailing drifters, many coming from other ports, assembled here for the summer herring fishing from July to September. Curing and kippering of the herrings was carried on. Two steam trawlers were also based in this port, at the time when beam trawling was taken over by steamers. Neither trawlers nor drifters work out of Montrose now. A few lines and seine boats are the sole survivors of a prosperous industry.

In the hey-day of the fishing on the coast of Angus, line fishing was the main industry. It was carried on during much of the year, and was interrupted for the herring season. Line fishing involves more labour than net fishing, and that possibly accounts in part at least for its abandonment. Crabs and lobsters are still fished for on the coast. Dundee is now the most important fishing centre; several trawlers work steadily out of the port, but their catches are now smaller than formerly."

A further note on herring is given on page 47.

Salmon Fishing. The salmon stake nets are familiar sights at various points on the Angus coast, the sweep net, however, being used in the Tay. The historical, scientific, commercial, and legal aspects of the Tay salmon fishing have been excellently treated by Mr W. Malloch (31). The author recalls how at the end of the thirteenth century Edward I. overran Scotland, bringing with him trained fishermen, so that many a barrel of Tay salmon must have accompanied the Stone of Destiny to London. But centuries earlier salted salmon were trade goods for Bruges cloths, Bordeaux and Rhine wines, and other continental amenities of culture, dress and table. Salmon sent to Newcastle were there pickled in vinegar, becoming thereby "Newcastle Salmon." In the eighteenth century, Perth had its own fish curing establishments trading with London but, later, fresh fish reached that market by the use of ice packing and fast sailing smacks. For the size of the river the numbers of salmon caught in earlier times were astonishing. During the decade 1788-1797 the Kinfauns Fishings alone obtained 87,000 salmon and 17,070 grilse, while after 1797, when stake net fishing was revived, a single net over one season at Errol captured 7,000 fish. It is no wonder that the apprentices of earlier times stipulated that salmon should not be served them more than three times a week. The stake net fishing depleted the fisheries, but its prohibition in the estuary and river in 1814 brought about an immediate improvement, the Kinfauns Fishings between 1815-1824 returning over 90,000 salmon and nearly the same number of grilse, the gross rental of the river reaching £14,592. But the use of stake nets on the coast in 1820 led to hard times for the salmon tacksmen of the Tay, and the more rational exploitation of the fishery did not occur until after scientific investigation and legal action based on such.

Regarding the life history of the salmon, it was not until after 1853, from experiments initiated at Stormontfield, Perthshire, that parr were proved to be the young of salmon. This led to the passing of the Act of 1868 under which parr and smolts are fully protected. On the formation of the Tay Salmon Fisheries Company in 1899 this body conducted further scientific work, among the consequences of which was the earlier closing of the netting season, the curtailment of netting stations and an energetic campaign against predatory animals.

The migration of smolts of salmon and of sea trout were studied in the Tay in 1903 and 1904 by the Fishery Board of Scotland (32, 33). It was found that the smolts gathered in great numbers at a fixed rather restricted area in the tidal waters four miles below Perth. They then moved off, sea-trout first, with some abruptness to the sea. The sea-trout smolts could be taken on the ebb and flood tides below the Dundee-Tayport line, but the salmon smolts went out to sea on the ebb tide and made no temporary return to the flood.

In May and June, 1905, at Kinfauns, the Tay Salmon Fisheries Company began research on the life history and movements of the salmon by marking 500 smolts with a fine silver wire inserted in the dorsal fin, Mr P. D. Malloch, the Managing Director of the Company, originating and supervising the work. The results showed that salmon returned to the same river the year after and later, and that some could make a second return, after they had spawned once in the river and gone down to the sea as kelts. These results were correlated with and firmly established the science of scale reading from which,

by studying the rings and zones of scales, the age of the salmon can be determined and some idea also of the condition under which it has lived during growth.

With the view to elucidating the factor which caused the final departure of the smolts from their temporary gathering area to the sea, the Board arranged for a further research in 1931, with Mr J. Berry as observer (34). The results from marked fish show that the maximum intensity of sea trout migration occurred during May 4-9, that of the salmon smolt during the next week, May 11-16. At the higher assembling areas the arrival and departure are more gradual than at lower assembling areas where, also, a shorter halt is made. The chief factor governing the halts is suggested to be temperature, not current velocity; that governing descent is storm, though this is more noticeable in salmon.

Sprat and Sparling Fishing. The principal fishing now carried on in the estuary is for sprats (*Clupea sprattus*) and sparlings (*Osmerus eperlanus*), six boats operating from Dundee and two from Newburgh, between September and March. The boom net, introduced from England, is used. This fishing has declined (Newburgh once had 34 boats) for the sprats are uncertain in their appearance and quantity, and prices, too, are uncertain. Sprats preponderate in the nets from October to December, but in January the young herring predominate (Malloch, 35). The sparling can be more or less abundant from April to June, being most plentiful at the beginning of May, the April catches being mostly kelts in poor condition, though many may be still distended with spawn. Fry may be found in huge numbers at the end of April (Berry, 34).

Other Fish. The following records are given by Berry (34) for the period April-June, 1931. The trout was found as "Whitling" and as "Yellow Trout." The stickleback (*Gastrosteus aculeatus*) was taken regularly, the common fresh-water and laterally-keeled estuarine forms being about equal in number. The lampern (*Petromyzon fluviatilis*), occurring at the end of April and the beginning of May, were of two distinct types: the larger kind, 9-12 inches; and the smaller and darker kind, 4-5 inches, possibly the doubtfully distinct species the pride (*P. planeri*). Both Alexander (21) and Berry (34) note the following: the viviparous blenny (*Zoarces viviparus*); the eel (*Anguilla vulgaris*)—noted by Berry as small and brown, about a foot, or sometimes larger and grey, few elvers being taken in April and May; the flounder (*Pleuronectes flesus*)—according to Berry the most abundant of all fish, several hundred sometimes being netted in an hour. Alexander also records the plaice (*Pleuronectes platessa*), the gunnel (*Pholis gunnellus*), the goby (*Gobius pictus*), the angler (*Lophius piscatorius*), and a bull-head (*Cottus scorpius*).

From intimate knowledge Mr J. Cameron informs us that the fishes of the Isla are: marine lamprey (*Petromyzon marinus*); river lamprey (*P. fluviatilis*); salmon (*Salmo salar*); sea trout (*S. trutta*); brown trout (*S. fario*); grayling (*S. thymallus*); pike (*Esox lucius*); perch (*Perca fluviatilis*); three-spined stickleback (*Gastrosteus aculeatus*); loach (*Nemachilus barbatulus*); minnow (*Leuciscus phoxinus*); eel (*Anguilla vulgaris*). The fish restricted to the lower Isla (Den of Airlie to Islamouth) are the migratory marine lamprey, salmon, sea trout and eel. All these fish are indigenous, except the grayling, which is a naturalised species.

MOLLUSCA.

The authority on the local molluscs, the late Mr H. Coates (36), concluded that Perthshire is very rich in mollusca. Of the 121 species recorded for Scotland 93 are found in Perthshire, 58 of these pertaining to the Carse of Gowrie. Of the last, 5 are by no means common in Scotland: *Hyalinia radiatula*, *Helix aspersa*, *Vertigo antivertigo*, *V. pygmaea* var. *pallida*, *and Limnaea palustris* var. *elongata*; and 4 are Scottish rarities, viz., *Ashfordia granulata*, *Hygromia striolata*, *Sphyradium minutissimum*, and *Limnaea glabra*. The small snail, *Hydrobia jenkinsi*, a recent invader from the sea of the brackish waters of Great Britain and the Continent, is one of the two molluscs—the other is American—which lacks males or male organs and reproduces by virgin birth, that is, is parthenogenetic. Dr. Ann R. Sanderson, who has studied the species cytologically, informs us that the Huntly Burn specimens are the non-keeled forms characteristic of less brackish water. Coates (36) and Alexander (21) do not mention the type they collected.

The pearl mussel (*Unio margaritifera*) is found in the South Esk, in the Tay above Perth, and probably in other Angus rivers. The Tay was the principal seat of British pearl fishing, its value between 1761-1764 being £10,000. To-day, owing to over-fishing, the fishing is of little value (Coates, 37). For other records of fresh-water molluscs see page 46 and Scott (47, 48).

INSECTS.

From previous records and from recent work principally relating to the Clova district, a considerable amount of information on several insect orders has been compiled in the Natural History Department, University College, Dundee. It is not yet in form for general publication, but is, however, available for specialists. In this article, therefore, attention is confined to a few special studies on insect ecology and insect pests.

The Insect Fauna of the Higher Altitudes has been treated by J. C. Willis and I. H. Burkill in their important paper "Notes on the Anthophilous Insect Fauna of the Clova Mountains" (38, 39).

Over the period 1894-1899, during the spring, summer, and autumn, these workers made 17,306 observations on individual insect visits to flowers, principally by hymenoptera, lepidoptera, diptera and coleoptera. Many of their conclusions are too technical for inclusion here, and mention can be made of a few features only.

The highest percentage of visitors, 66.76, was obtained by the short-tongued diptera, the other groups showing small percentages in the following descending order: coleoptera, 7.47; mid-tongued diptera, 6.58; *Bombus* and *Psithyrus*, 5.41; Apis, 2.47; long-tongued lepidoptera, 2.29.

The authors distinguish five zones in ascending order—strath, second belt, third belt, crag belt (2,000-2,500 feet), high moors, and also deal with the altitudinal distribution of the hymenoptera. The strath forms, chiefly humble-bees, are the early humble-bee, *Bombus pratorum* L., mostly found in the strath; two carder-bees, *B. agrorum* F. and *B. venustus* Smith, the latter rarely leaving the strath; the small garden humble-bee, *B. hortorum* L., and buff-tailed humble-bee, *B. terrestris* L., both most abundant in the strath, but also found at the high levels; also the mid-tongued hymenoptera such as Odynerus and the wasps, low level forms; and sawflies such as *Allantus*

arcuatus. The third belt Bombus is the bilberry humble-bee, *B. lapponicus* F., more common above 1,000 feet than below; it is the chief Bombus to visit the Alpine flowers. At all heights is found a cuckoo bee, *Psithyrus quadricolor* Lep. Also mentioned are *B. Scrimschiranus* and *B. ionellus*.

The flower-visiting lepidoptera are greatest in variety in summer, while the autumn maximum is due to a few species present in large numbers. The spring long-tongued lepidoptera are chiefly the butterflies, the small tortoise-shell (*Vanessa urticae* L.), and the green-veined white (*Pieris napi* L.). The chief summer species is the common blue (*Lycaena icarus* L.), but there also occur, among others, the dark green fritillary (*Argynnis aglaia* L.), the small pearl-bordered fritillary (*A. selene* Schiff.), the small heath (*Caenonympha pamphilis* L.), several species of Plusia and *Eriocephala calthella* L. The autumnal moths were mainly the ear moth (*Hydroacia nictitans*), Haworth's minor (*Celaena Haworthii*, Curts.), while the somewhat autumnal small copper butterfly (*Polyommatus phloeas* L.) also occurred.

The flower-visiting coleoptera showed an increase to autumn. In spring they are rare; in summer there are many species, *Meligethes viridescens* F. and *M. aeneus* F. being the commonest, followed by *Epuraea aestiva* L., with *Anthophagus alpinus* Payk. quite common; the autumn abundance was due to the two species of Meligethes.

The notable Alpine insects are few, namely: Hymenoptera — the bilberry humble-bee, *B. lapponicus*; Lepidoptera—the small ringlet, *Erebia epiphron* Kn.; the black mountain moth, *Psodos trepidaria* Tr.; the crambid moth, *Pyrausta alpinalis* Schiff.; Diptera—two species of "bird's beak flies" (*Empis vernalis* Mg. and *E. lucida* Ztt.); a "blossom fly" (*Limophora solitaria* Ztt., Anthomyidae); a "daddy-long-legs" (*Tipula excisa* Schum.); Coleoptera—a "blossom beetle" (*Anthophagus alpinus* Payk.).

Some interesting observations are made on many species of hover flies and their reactions to flower colour. For instance, *Chilosia fraterna* was always taken on flowers of bright yellow colour, whilst *C. sparsa*, *C. antiqua*, *C. bergenstammi*, and *C. scutellata* were observed principally on yellow flowers, *Chrysogaster hirtella* probably showing a similar preference. But *Rhingia campestris*, which visited eleven species of flowers, chose those with more or less blue in them, and no other syrphid showed such a favouritism for this end of the spectrum; *Sericomyia borealis* visited the lilac-blue *Scabiosa succisa* freely, but no other flower of that hue; *Eristalis rupium* and *E. arbustorum* seemed to avoid the extreme of blue. The small syrphids tended seemingly to prefer white and yellow flowers, though *Platychirus manicatus* visited flowers of lilac-blue, rose-purple, white, and yellow with almost equal partiality.

Aquatic Coleoptera. The major part of our knowledge of the local beetles concerns aquatic forms, studied by F. Balfour-Browne (40). Altogether 84 species are listed for Angus, the genera showing the most species (number given in brackets) being Hydroporus (20), Agabus (11), and Haliplus (8). Several distributional notes are of interest: *Hyphydrus ovatus* L. has not hitherto been recorded north of Midlothian; *Deronectes griseo-striatus* De G. occurs almost entirely in small highland lochs and large peat holes from 800 feet upwards and is restricted to Scotland and Ireland (with the possible exception of Cumberland); *Hydroporus lineatus* F. was not found elsewhere than in one small loch, where it apparently reaches its northern limit;

Agabus affinis Payk. is known in only 14 of the 40 Scottish counties and vice-counties, from Eastern Inverness southwards; *Agabus congener* Payk. is a typical mountain species of wide distribution; *Ilybius subaeneus* Er. has not been recorded elsewhere in Scotland, and in view of its restricted distribution in England the author raises the question as to whether the species has declined in the south and has recently become established in Scotland; *Acilius fasciatus* De G., common at Restenneth, but not found more north, is now a northern and mainly Scottish species and is possibly another case of an insect which has declined in England and colonized Scotland; *Octhebius lejolisii* Rey and Muls provided a new record for the east coast of Britain. The forms of *Deronectes depressus* F. and *D. elegans* Panz. show a fairly complete range from extreme *depressus* to extreme *elegans*, but the data do not allow a decision as to whether they are separate species which hybridize or are a single variable species.

Insect Pests. Despite its reputation as a fertile area for farm and fruit crops Angus has been little studied from the point of view of its agricultural pests. The wheat bulb fly (*Leptohyleomyia coarctata* Fall.) was investigated by Gemmill (41) at various points around Dundee and among the many important points noted were that couch grass (*Agropyrum repens*) appeared to be the natural host-plant of the pest; and that the areas in which the fly was most abundant were those in which most wheat is grown following potatoes (especially early potatoes), and in general the fields worst infected in any one year were those in which the previous year's root crop or fallow was close to infected wheat fields. Among a number of preventive and remedial measures suggested was that of avoiding the sowing of wheat after potatoes or other root crops of fallow. By this the author believed that the numbers of the fly would be so reduced that the pest would cease to be a menace for many years to come, during which the customary rotation could be followed.

Work on raspberry pests has but recently been begun locally. During the season 1938 Mr F. L. Waterhouse and Miss A. Adam, University College, Dundee, studied the conditions existing in a Longforgan raspberry farm and discovered the presence of the two well-known pests, the raspberry beetle (*Byturus tomentosus*) and the raspberry moth (*Lampronia rubiella*). It would appear that both insects are probably more serious pests than commonly supposed locally.

Malaria fever (ague) was once common in the Carse of Gowrie and Angus, as in other places of Scotland (James Ritchie, 16), and although not known to-day it is probable that the insect vectors of this disease, mosquitoes of the genus Anopheles, still exist in the Carse, for W. Keir (42) has obtained *Anopheles bifurcatus* from Downfield, Dundee. The late Professor J. H. Ashworth (43) records a possible case of indigenous malaria at Kirriemuir just after the Great War, the organism being possibly derived from soldiers affected abroad.

Lepidoptera. Very little local work has been done in this group and the status of such species as are recorded is not worked out. A list of 55 species of Noctuae, captured in 1893 near Montrose, is given by Gunning (44), and a second list (45) of 123 butterflies (a few) and moths taken in 1895 near Montrose—on the coast, on sandhills, on heather, sallow and ragwort, and by sugaring. Certain of his 1895 collection (45) were unusual local appearances, namely, the brindled green (*Hadena protea*), merveille du jour (*Dichonia*

aprilina), and the cinnabar (*Euchelia jacobaeae*), which, however, we know to be common at Monifieth and Tentsmuir. Variations from this type were also remarked in certain noctuids, namely, the Hebrew character (*Taeniocampa gothica*), the autumnal rustic (*Noctua glareosa*), the clouded bordered brindle (*Xylophasia rurea*), the marbled coronet (*Dianthoecia conspersa*), and the green brindled crescent (*Miselia oxyacanthae*).

Observations on the coloration of local specimens of light sensitive caterpillars have been made in Glen Clova and Glen Doll by Harrison (46). Certain larvae of the November moth (*Oporinia autumnata*) taken from birch were yellow green instead of bright apple green. The larvae of the December moth (*Poecilocampa populi*) obtained from *Salix aurita*, a pale habitat, were very light in colour, whereas those found on alder, both in the glen and elsewhere, were dark. The larvae of the scalloped oak (*Crocallis elinguaria*) found on a very unusual food-plant, red currant, also showed adaptive coloration.

Alpine forms are the small mountain ringlet (*Erebia epiphron* Kn.), the black mountain moth (*Psodos trepidaria* Tr.), and the crambid *Pyrausta alpinalis* Schiff., noted by Willis and Burkill (38).

Crustacea.

Little is known of local crustacea except the records in "The Invertebrate Fauna of the Inland Waters of Scotland" by Scott (47, 48). In the first paper the crustacean and molluscan faunas of Loch Rescobie and the connected Loch Balgavies are briefly dealt with and the number of crustacean species for each loch was practically the same, being, respectively: Amphipoda, 1,1; Copepoda, 15,12; Ostracoda, 12,10; and Cladocera, 16,17, though the numbers of mollusca were markedly different, Rescobie having 11 and Balgavies 3, a result which may be accidental. A copepod new to science, *Canthocamptus inornatus*, another new to Great Britain, *Cyclops varicans* G. O. Sars, and a rare ostracod, *Darwinula Stevensoni*, were discovered in both lochs. The second paper deals with Forfar Loch, the species being: Amphipoda, 1; Copepoda, 18; Ostracoda, 18; Cladocera, 13; Mollusca, 14, including *Anodonta cygnea* found in the burn outflow. Specially interesting are the occurrence of the copepods *Canthocamptus inornatus* (mentioned above), and *Moraria brevipes*, rare in Scottish lochs; of the ostracods *Cypris pubera* and *Ilyodromus violacea*, rare to Britain; and of the somewhat rare *Leydigia quadrangularis*, observed only in a few Scottish localities.

Platyhelminthes.

Several new local larval trematode worms and larval tapeworms parasitic in fresh water and land invertebrates have been investigated by W. F. Harper (49-53), and some have been related to the adult forms by infecting ducklings. The host animals include water and land snails, larvae of alder flies, caddis flies, diptera, ostracods, an amphipod, a land oligochaete, and a turbellarian.

Rotifera.

About 100 species of local rotifera are recorded for the Tay in Hudson and Gosse's monograph (54), which describes about 400 British and foreign species. These local records were primarily due to Hood (see page 31). We possess

Hood's copy of this monograph and it is of particular interest because many of its annotations and sketches are by Hood himself. He gives a list of 65 new species discovered by him, some of which bear the name *hoodi*; another list of 19 species, the males of which he was the first to find; a third list of 36 species from the domestic water supply; and another of 35 marine forms collected from the Tay, only 8 marine forms having been previously recorded. In addition, he lists 62 species of infusoria from Dundee Harbour and 12 hydroids from the river and harbour. The monograph repeatedly reflects the authors' high estimation of Hood, and one of Hood's own annotations also illustrates this. He comments that, although the species *Oecistes mucicola* and *Oe. socialis* were first described respectively in America and in Geneva, he had sent these, believing them to be new, some years previously to Hudson, who, however, considered them to be *Oe. crystallinus*. When these foreign authors had published their description, Hood again drew Hudson's attention to the matter, but the upshot, in Hood's own words, was " His reply oh never mind a new Rotifer is not a pet lamb to you now."

Rare and Unusual Records.

Mollusca. Interesting records of cephalopods exist for Angus. The octopus, *Octopus vulgaris* Lam., was found on the beach at Montrose in 1893. The giant squid, *Architeuthis harveyi* Verrill, has also been obtained. A trawler fishing off the Bell Rock near Arbroath captured a living specimen on 7th January, 1937, but in the struggle of handling it all that was secured were the two long arms, 15 feet 2 inches and 17 feet 6 inches long, and one of the short ones, 3 feet 9 inches. The body length must have been about 7 feet. Large numbers of the squid, *Todarodes sagittatus*, Lam., were cast up along the banks of the Tay estuary, and at various localities between Montrose and Dunbar, in February, 1937. The body length of the specimens reached 21 inches. The species occurs in the open waters around Britain and rarely a winter passes without an occasional stranded specimen being seen, but the reasons for the mass invasion and strandings of this particular year are unknown. The suggestion that they came ashore for spawning is negatived by the fact that the many specimens examined were immature. All these are referred to by Stephen (55).

Amphioxus. A specimen of the lancelet, *Branchiostoma lanceolatum* Pallas, was picked up on the beach at Montrose some few years before 1937. This is only the third record for the east coast of Britain, the other localities concerned being Norfolk and the Moray Firth. As the Montrose ground has sandy gravel or shell gravel, it is possible that further search will bring other specimens to light (Stephen, 55).

Fishes. Of rarities there are the belted bonito, *Pelamys sarda*, Cuv., taken at Montrose (see Day, 56), and the bass, *Labrax lupus*, Cuv., obtained off the Bell Rock in 1909, a first Scottish record (Thompson, 57). A recent interesting occurrence was the stranding of the curious oar-fish or King of the Herrings, *Regalecus glesne*, Ascan., at Westhaven in April 1938. It was a female, 17 feet 10 inches long, probably a record length for the occasional specimens found stranded in the British Isles (Peacock, 58).

A recent invasion of herring shoals to the Tay is of unusual interest. Formerly the estuary provided good herring fishing, but for nearly thirty years past the quantity of herrings has declined almost to vanishing point.

Then, in February, 1936, a remarkable influx of the fish occurred and provided drift net fishing for a few Broughty Ferry row-boats, as well as seine net fishing for a number of visiting motor-boats. Investigations were made by the Natural History Department, University College, Dundee, and Miss C. F. Drysdale reports (unpublished work) that the bulk of the catch belonged to the two-year class, the fish averaging 6.7 inches, though there occurred 4-5 inch specimens of the one-year class, and others up to the five-year class, of which the longest was about 10 inches. Only a few, the largest, were mature. The fundamental hydrographical and other causes involved, despite enquiry, are unknown, though it is possible that the shoals were actually making for the Forth.

The Musk-Rat Menace. The story of the musk-rat (*Fiber zibethicus*) in Scotland is that of a promising, if risky, scheme gone wrong. By its introduction the local waterways might have been populated by an undesirable alien which would certainly have produced far-reaching effects on the local "balance of nature." Fortunately, as it happened, the few local isolated invaders were killed (Munro, 59 ; *Glasgow Herald*, Dec. 27, 1932 ; *Dundee Courier and Advertiser*, March 23, 1934 ; *Daily Herald*, May 14, 1935). In 1927 six pairs of musk-rats were brought from Canada as the nucleus of a fur farm at Feddal, near Braco, Perthshire. Most of them escaped by biting through the wire netting of their enclosure and spread to give rise to numerous progeny which established themselves in Perthshire and Fife. The animals are elusive, live in deep burrows and in winter lodges, are healthy and prolific, and the damage they do to river and canal banks on the Continent is so enormous that a constant warfare is waged against them. The threat to our countryside was met by official action in 1932 and the campaign against them was led by Mr Munro of the Department of Agriculture for Scotland, assisted by Herr Roith, a Bavarian trapper expert. Up to September, 1934, the number of musk-rats trapped in the basins of the Forth and Earn was 945, in Scotland generally 1,085, all the seven years' progeny of five females and four males. In addition to records from the Earn, there are those of seven local single spies. One, not officially identified, was killed on June 13, 1931, near Dryburgh Farm, Dundee-Coupar Angus road. Another, now in the possession of the Dundee Sanitary Authority, was killed on March 13, 1933, on the same road. A third was shot by Mr William Berry on April 26, 1933, in his grounds at Tayfield, Newport, Fife, its length being 22 inches, and its weight 21 lbs. 5 oz. (data by kindness of Mr Berry). On July 18, 1933, another specimen was trapped near Tentsmuir, and on May 23, 1934, a kill was made at Glamis. The latter must have left the Earn for the Tay, journeyed up to the Isla, and from thence to Dean Water at Glamis. Another, 23 inches long, was killed by a dog on May 23, 1935, near Dairsie, River Eden. The last record relates to a specimen, 23 inches long, taken on June 17, 1935, at Broughty Ferry.

Aquatic Mammals. The common seal (*Phoca vitulina*) is a permanent resident on the sandbanks at the mouth of the Tay estuary and still penetrates as far as the sandbanks above the Tay Bridge, and even to Perth. Doubtless the warfare waged against it in the interests of the salmon fishing has greatly discouraged its venturing far from the safety of the more remote Tayport sandbanks. A stray harp seal (*Phoca groenlandica*) is recorded for Invergowrie Bay, September, 1895 (Harvie-Brown, 3).

Of whales, the common porpoise (*Phocaena communis*) has been found in large shoals as far as Errol, and a school of small pilot whales (*Globicephalus melas*), the largest not less than 22 feet long, appeared in the Tay on October 6, 1817, twenty to thirty of them being killed (Harvie-Brown, 3). The common dolphin (*Delphinus delphis*) apparently does not often frequent the North Sea, but individuals occasionally straggle into local waters. Two specimens were obtained between Buddon Ness and Monifieth in February, 1937, and yet another was examined in the same month and year at Arbroath by Professor Peacock. Their occurrence was very probably due to their following cuttle-fish which had invaded the North Sea (see p. 47; also Fraser, 60). Of other records there are white-beaked dolphin (*Lagenorhynchus albirostris*), stranded at Whiting Ness (Stephen, 61); bottle-nosed whale (*Hyperoodon rostratus*), once at Carnoustie, 1916 (Harmer, 62), and once near Tayport (Greenshields, 63); finner whale (*Balaenoptera physalus*) from the Bell Rock, Arbroath, 1918 (Harmer, 64); and four specimens of the lesser rorqual (*Balaenoptera acutirostrata*), stranded at Buddon Ness between 1913 and 1922 (Stephen, 65).

The most important occurrence was the great stranding in November, 1935 of 41 false killers (*Pseudorca crassidens* Owen), at Buddon Ness, Angus, and of 7 at Kinkell, Fifeshire (Peacock, Comrie and Greenshields, 66). There were 27 females (each of two with a foetus) and 21 males, and there appeared to be three size-groups for each sex; among the females the size-group comprising the greatest number ranged from 14 feet to 15 feet 6 inches, the other two size-groups being between 12 to 13 feet and about 9 feet; among the males the size-group comprising the greatest number ranged from 15 to over 19 feet, the other two being between 12 to 14 feet and between 9 and 11 feet. The males are evidently the larger. The ages of the representatives of these groups were then estimated to be, respectively, three years plus, two years and one year. Later investigations on the corpora lutea (Comrie and Adam, 67) allow the tentative suggestions that the age-range of four of the largest females was 3 to 4 years as a minimum and 12 to 20 as a maximum, with a mean of 7½ to 12 years, while two others were possibly twice as old. There are indications that the species sheds a single egg at each of a number of periods in the year, the winter months excepted. The dental formula for both sexes was characteristically 8/9 for upper and lower jaws respectively, though the numbers varied from 6 to 11.

Following this event, Fraser (68) gave an interesting account of the species. The false killer is a typical oceanic dolphin and its strandings, some of them of a wholesale nature, are recorded for various parts of the world. The winter strandings of 1935 on the east coast of Britain, of which that of the Tay was only one, mark the third appearance of the whale to Great Britain, the previous ones being at Dornoch Firth in October, 1927, and at Glamorgan in May, 1934. A satisfactory explanation of the 1935 strandings is not yet forthcoming, but as the circumstances render remote the possibility that they were due to migrations associated with reproduction, Fraser suggests that they resulted from the whales pursuing their fish and cuttle-fish food into unusual regions which proved to be dangerous by reason of shoal waters. That a change had possibly occurred in the distribution of the whales' food supply is borne out by the fact that since 1930 there had been an increasing strength of Atlantic flow into the North Sea.

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A SCIENTIFIC SURVEY OF

DUNDEE AND DISTRICT

PREPARED FOR
THE DUNDEE MEETING 1939

BY VARIOUS AUTHORS

Edited by
R. L. MACKIE, M.A., B.Litt.
Training College, Dundee

These surveys, since their initiation in 1932, have been issued to members attending the Meetings, and have subsequently been included in the Annual Reports. The intention in future is to include the survey for the forthcoming meeting in the July issue of 'The Advancement of Science' preceding such meeting; whether that scheme will be possible in 1940, however, cannot be forecast. Meanwhile the Dundee Survey is continued here from No. 1 of 'The Advancement of Science,' and will be concluded in No. 3.

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VI.

AGRICULTURE IN THE DUNDEE DISTRICT

BY

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THE Dundee District, which may be taken to embrace the greater part of Angus, the north and east of Fife, and east Perthshire, includes lowland, upland, and mountain districts, and its systems of farming are largely determined by the elevation.

In the low country there is a large proportion of good or excellent agricultural land, and the general standard of farming is high. The soils vary, but are mainly friable reddish loams, of good depth, which suit a wide variety of crops. Few fields are too heavy for potatoes or swedes, and few are too light, given generous manuring, to yield satisfactory crops of wheat. The whole area having been glaciated, there are no marked differences between the soils overlying the Old Red Sandstone, the Carboniferous Limestone Series (which occurs in East Fife), and the volcanic rocks which run in a series of belts from south-west to north-east through all three counties.

Three exceptional soil types must be distinguished from the general run of medium loams. Here and there, in the valleys, are considerable areas overlaid by hillocky masses of morain sands and gravels, which give rise to light burning soils of little value. Examples are to be seen along the railway between Cupar and Dundee, round Gleneagles, and scattered along Strathmore. Secondly, there are areas of coastal sand-dunes, the largest being those on both sides of the lower Tay Estuary—Barry Links on the north and Tents Moor on the south. Most of this land is willingly resigned by the farmer to the golfer and the forester. In places the sand has been blown inland for some distance and has covered what was originally good soil. In the early part of the seventeenth century numbers of fields above Carnoustie were so deeply smothered that they passed out of cultivation for more than fifty years,* and have never since fully regained their fertility.

The third and most important exception is constituted by the Carse of Gowrie, a belt of rich, heavy alluvium lying along the north bank of the upper Tay Estuary and comprising nearly forty square miles. The land on both sides of the Earn, below Bridge of Earn, is similar. Some islands of loam stand up above the old river level, but the carse-land proper is a strong clay, too heavy for the satisfactory cultivation of roots or potatoes, but yielding very heavy crops of wheat, beans, and hay. Until the present century the Carse was largely arable, farmed under wheat, beans, hay, oats, and bare fallow ; but in recent years a good deal has been laid away to grass, the better pastures being used for cattle fattening. As root-growing is hardly

*Edwards' *County of Angus*, 1678.

possible, a good many of the farms have been equipped with tower silos, the crop used for ensilage being a mixture of beans, oats, and vetches. The Carse had at one time a reputation for its apples, and some old orchards still remain, though they are of little value.

Where there are steep escarpments, such as the Braes of the Carse and those of north Fife, the soils are, naturally, thin and rocky. On the leveller reaches of upland we get mainly "moorish" land, often lying on a boulder-clay subsoil which makes for difficult drainage and late spring growth. Where the drainage is completely impeded there are peat-bogs which, up till the nineteenth century, were the main sources of fuel for rural people. Many have been drained and reclaimed, but most have made only moderate farm land. Above the seven- or eight-hundred-feet contour are considerable areas of unreclaimed heather moor, used as sheep grazing. The largest is on the Sidlaws, which rise to nearly 1,500 feet.

North-west of Strathmore, as soon as we cross the Highland Fault, we reach typical Highland country, with narrowing belts of improved and enclosed land stretching up the glens, and wide expanses of heather-clad mountains between. The smaller farmers of the lower glens are chiefly cattle-breeders, while the large mountain grazings are given over to Blackface sheep.

The rainfall of the low country is generally under rather than over thirty inches, and the summer temperatures allow of the ripening of the majority of the common British crops. Winter wheat matures well up to an elevation of four or five hundred feet, and goes higher where the exposure is favourable. In many seasons some sowing of oats (of the variety "Marvellous") is to be seen in Fife as early as January or February, and the main spring sowing of cereals can generally be begun, in the lower districts, soon after mid-March; corn is commonly ripe by the third week of August. High yields of barley can be produced, but the malting quality does not compare favourably with that of samples grown in East Anglia, or even in East Lothian. The best local samples come from the coastal districts of Fife. Oats flourish on all but the lightest soils; yields are probably as high as can be found in any part of the world, and the quality of the grain, in years of good harvest weather, is excellent. Mangels can be grown, but swedes and turnips give heavier yields. There is a beet-sugar factory at Cupar, and fields of beet are to be seen up to elevations of four or five hundred feet. The yield of sugar varies a good deal with variations in the season, the amount of sunshine being the most important factor. The average yield of washed roots may be eight or nine tons per acre. The cool climate is admirably suited to the production of healthy stocks of seed potatoes, and the potato is easily the most important cash crop.

A good deal of the past history of the countryside can be deduced from the lay-out of the fields and from the place-names. In the more fertile parts of the low country the great majority of the farm names are Gaelic, the commonest prefixes being Bal- (*Baile*=a farm town or hamlet), Pit- (*Pett*=a portion of land) and Ach- (*Achadh*=a field). Such names, except perhaps in the vicinity of the Highland Line, indicate farming settlement earlier than the thirteenth century. In many cases the modern farm descends directly from the original run-rig township, while in others the addition of a Scots or English word tells of a division of the old unit into separate farms; local examples are Milton of Craigie, East Pitkerro, New Downie, Newton of Affleck, East Mains of Balmuir, etc.

The organisation of the local townships, some of which survived until the eighteenth century, was much the same as in other parts of Scotland, and is well illustrated in the *Rental of the Monastery of St. Marie of Cupar* (Coupar Angus). Thus in 1542 Coupar Grange, which is now a single large farm, was let to twelve tenants, each of whom had an equal share and paid, in annual rent, 26/8 Scots in money, 15 bolls 1 peck of barley, 3 bolls of oats, and 12 capons; provided the carriage of seven score and sixteen loads of peat and supplied twelve trusses of fodder (probably oat straw), with "common careage when they are chargit."

By contrast with the ancient farms of the fertile districts, the uplands generally show all the signs of recent reclamation and settlement. The farm names are such forms as Denside, Whitehouse, Bankhead, etc., the fields are rectangular, and there is other evidence of careful planning. In fact, most of higher land was still heather moor and bog until far on in the eighteenth century, and was reclaimed, for the most part, between 1760 and 1860. The work of reclamation involved the clearing of boulders, which in some parts were very numerous; drainage, which was done up till about 1845 by built stone drains and later by tiles; and, above all, the application of large quantities of lime. The lime required in the coastal districts was brought from Fife by sea, and some inland districts were supplied from local kilns; where limestone was inaccessible, the farmer fell back on deposits of shell marl, which occur in many of the lochs, and also under layers of peat on the sites of old lakes. Forfar Loch yielded large supplies of this material, and was successfully exploited by the Earl of Strathmore from about 1760 onwards. The water level of the loch was lowered by cutting a deep ditch, so that a good deal of the marl was laid dry, and the ditch was provided with a system of locks so that the marl could be taken by boat to the Earl's estate at Glamis.*

A further step of improvement was the extensive application of bones during the early part of the nineteenth century.

Concurrently with these reclamations of moor, and with the enclosure of the old township farms, were many other steps of improvement. Potatoes came into cultivation, as a field crop, after 1760, and the acreage has slowly but almost continuously expanded ever since. Turnips began to be generally grown about 1780, and there were considerable acreages of swedes by the beginning of last century. The sowing of leys, with mixtures of ryegrass, red and white clover, trefoil, etc., began about 1750, and the old tumble-down pastures of the outfields had disappeared by about 1780. Concurrently there were well-sustained efforts to improve the cattle, which provided the farmers of the time with the greater part of their cash incomes. The earliest improvers, about 1770, introduced Bakewell's Longhorn, but the results were not very satisfactory; in the end the farmers divided their patronage between the Shorthorn (which was first brought north by Barclay of Urie, in Kincardineshire, about 1825) and the Aberdeen Angus. The founder of the latter breed was Hugh Watson of Keillor, near Coupar Angus, who assembled his herd in 1810. Numerous pedigree herds of both breeds are still maintained in the district, and Perth has become the most important pedigree-sale centre, in the whole of Britain, both for the Aberdeen Angus and for the Scotch type of Shorthorn.

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*For a full account see Wight, *Present State of Husbandry in Scotland*, Vol. I. p. 274, 1778.

The impetus to cattle improvement was the improvement of communications, and the rearing and fattening of high-quality, early-maturing breeds were made possible by the use of bone manures for the improvement of the temporary pastures and for the production of heavy crops of swedes and turnips. Up till the early part of the nineteenth century the cattle for the English market were sold, as three- or four-year-old stores, at customary fairs (of which the largest was Trinity Fair near Brechin), and were taken south by drove-roads, many going as far as Norfolk to be fattened. Some fat as well as many lean cattle were shipped from Dundee and other ports in sailing coasters, but the voyage was often protracted, and the cattle suffered a good deal in stormy weather. The steamboats which began to ply in the early 'forties, and the railways which followed soon after, made it possible to send either fat cattle or sides of beef to London.

The generation which farmed from 1840 till 1880 reaped a rich reward for the labour and capital that their fathers had sunk in the land. In the 'sixties good low-ground farms were being let at figures like £3 and £4 per acre, but the prevailing custom of nineteen-year leases made for a long lag in rents, and tenants mostly throve. Serious depression did not come till the 'nineties.

The introduction of large-scale sheep farming to the Eastern Grampians began in the latter part of the eighteenth century. It was long considered that the winter climate was too severe for sheep, and the early system was to graze wethers on the mountains in summer and to take them to low ground for wintering. It was only after the middle of last century that breeding flocks were established. There are now some excellent flocks of a large and robust type of Blackface, and numbers of breeding rams are sold to other districts.

The most interesting of recent developments in the local agriculture has been the rapid increase in the area devoted to raspberry cultivation. In 1892 the total area of small fruit in the three counties was under a thousand acres. By 1912 this had increased to about 4,000, and by 1936 to 6,500. Of this last total nearly 5,600 acres were under raspberries. The chief areas of cultivation are round Blairgowrie (which was the earliest), Forfar, and Auchterarder, and the newest lies between Montrose and Brechin. The climate of the district seems to be almost perfectly suited to the crop.

We may now describe in outline the organisation of a few typical farms, and it seems most convenient to begin in the mountains and work downwards to the plains.

The typical mountain grazing extends to some thousands of acres, and each shepherd has a flock of perhaps five hundred breeding ewes which, in an average season, will produce over four hundred lambs. On the higher grazings the breed is uncrossed Blackface. The " top " ewe lambs are normally retained for breeding, but are sent down to the lowlands in November to be wintered on pastures, returning home in April. The " second " ewe lambs are sold to other hill farmers, on somewhat better land, who cross-breed with the Border Leicester. The wether lambs are sold in late summer and autumn to lowland farmers for fattening. The ewes are disposed of generally at five and a half years old, and all that are healthy are bought for breeding by farmers in the semi-arable upland districts, being crossed with the Border Leicester to produce " Greyface " lambs. The mountain grazings may carry a few ponies and occasionally some cattle.

The farms of the glens and hill-foot districts are both large and small. The better fields, and those lying near the homestead, are worked on the alternate system, the duration of the ley varying greatly. The ley is broken in autumn and sown with oats in spring; in the following year the crops are turnips and swedes, with usually a small area of potatoes; following this is a further crop of oats, with which is sown a grass-seeds mixture including wild white clover. The cattle stock generally consists of Aberdeen Angus or Cross-bred cows, which are mated to Angus bulls and suckle their calves. If the arable acreage is small the calves are sold in autumn, but if there is a sufficient supply of roots and straw they are kept round till spring. There are large special sales of such calves or "stirks" at Blairgowrie, Kirriemuir, etc., and since the quality of the stock is remarkably high, buyers come from long distances and high prices are realised. On all the larger upland farms flocks of ewes, generally Blackface, are maintained, and produce Greyface lambs to Border Leicester rams. The young cattle, lambs, and wool, with an occasional Clydesdale colt, and in some cases a relatively small quantity of potatoes (mainly for seed) provide the whole income.

Descending a further step we come to a zone where the great bulk of the land is arable, and where the traditional rotation is a six course—oats after ley; turnips, swedes, and potatoes; oats with grass seeds; and a three-year ley, part of the first year's grass being mown. Here the main income is still derived from livestock, but there is a wider choice of the particular enterprises, and there are normally sales of both potatoes and oats. If cattle are bred they are generally carried on to two years old and sold fat in spring. In other cases young stores are purchased, reared, and fattened. Where there is a convenient market for milk a dairy herd is an alternative possibility. On the larger farms there is normally a breeding flock of Greyface or Half-bred ewes, which are crossed with Suffolk or Oxford rams. The lambs may be sold as stores, or fattened in winter on roots. Numbers of Blackface and Greyface lambs are also purchased from the hill farmers, and are fattened on lattermaths and roots.

The typical farm of the lowland loam areas, such as Strathmore and the coastal belt of Angus, is rather large—perhaps three hundred acres in extent—and employing eight or nine men. The traditional rotation is a seven course, which runs as follows:—(1) Oats are taken after a two year ley, and are followed (2) with potatoes, which receive the bulk of the farmyard manure with perhaps 6, 8, or 10 hundredweight of artificial. The varieties are chiefly maincrops such as Majestic, King Edward, Kerr's Pink, and Golden Wonder. The potato crop is easily the largest single source of income. Majestic and King Edward are grown mainly to produce seed for the English market. Next (3) follows wheat, which can rarely be sown till the latter half of November, and which may get 2 or 3 cwt. of mineral fertiliser in autumn and a dressing of nitrogen in late spring. The wheat is succeeded (4) by turnips and swedes, or partly by sugar beet, which crops may receive light dressings of dung, but in any case get rather liberal doses of fertiliser. Next (5) comes oats or barley, the choice depending on the character of the particular field and the prospects for barley prices. With this grain crop is sown the grass seed for a two year ley (6 and 7).

As in other districts, there is now a tendency to depart from a strict succession of cropping and, in particular, to leave the ley down for three or even four years.

Up till the period of the war almost the only livestock on these lowland farms, apart from the work horses, were fattening bullocks. The farmer reckoned to feed in winter two or perhaps three bullocks on each acre of his root crop, along with oat straw, a very little hay in the last stages, and an allowance of 4-8 lb. per head per day of cake and other concentrates. A further batch of stores was bought in spring and fattened out on grass. The district is far from being self-supporting in the matter of store cattle, large numbers of Irish being imported both in autumn and spring.

With the long continued depression in beef prices, the livestock has become much more varied. In the vicinity of towns, and even fairly far afield, there are dairy herds. " Regular " breeding flocks, except pedigree flocks of Border Leicesters, Suffolks, and Oxfords, are not very common, for the ewes tend to get too fat. Most farmers, however, have flying flocks of Half-bred or Greyface ewes for the production of fat lamb. Considerable numbers of lambs and tegs are also bought and fattened. Large-scale pig breeding and poultry keeping are rather uncommon, though numbers of fowls are increasing.

The general standard of farm building and equipment is high, for there was great enthusiasm for improvements on the part of the landowners throughout the period 1760-1890. The tenants are progressive and hard-working men, and it is doubtful whether keener or more highly skilled workers are to be found in any part of this country ; nevertheless, the area has suffered, in full measure, the effects of recent depression, and is probably less prosperous now than it has been for a century and a half.

VII.

PREHISTORIC ARCHAEOLOGY OF THE DUNDEE DISTRICT

BY

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Mesolithic. The earliest reliable traces of man so far recorded in Scotland date from the ill-defined period after the Quaternary Ice Age which archaeologists term "mesolithic." To an early phase of this period might be assigned on geological grounds a canoe hollowed out of a trunk of Scots' fir with the aid of fire which was found "a number of years" before 1879 at Friarton brick-works, Perth, beneath 10 ft. of estuarine silt on a bed of peat. The silt is equated by James Geikie with the carse clays, admittedly laid down in the period of marine transgression represented elsewhere by the "25 ft. raised beach" and coinciding with the Atlantic or Lower Turbarian phase of climate. The underlying peat was presumably formed before the transgression in the preceding Boreal or Lower Forestian climatic phase. Assuming that the dug-out canoe came from this peat, it would be contemporary with Continental sites such as Maglemose and Kunda, and anterior to 5000 B.C.

No other associated relics, found in our area, can be dated to the mesolithic with any confidence. But a few pigmy flints or microliths from Tentsmuir may belong to the Tardenoisian culture which appeared in England first in Boreal times, but even there persisted very much later.

The Neolithic Period is represented by no connected remains in the area here surveyed. Certainly there are plenty of polished stone axe-heads, the type fossil of the New Stone Age for typologists, but such notoriously remained in use during the subsequent metal ages. In fact the only specimen found in a definite association in our area comes from the Iron Age fort at Abernethy (p. 61). Similarly flint arrow-heads of the leaf-shaped type, which alone was current in neolithic Britain, is commoner than the tanged-and-barbed variety that came in first with the Beaker invaders at the beginning of the Bronze Age. In a representative sample collected in Angus, 61 arrow-heads are leaf-shaped, only 42 tanged-and-barbed; from Tentsmuir, Fife, St. Andrews University Museum possesses 12 of the former type and 40 of the latter. Grave-finds, however, prove that leaf-shaped arrow-heads were not confined to the Stone Age, but were used quite late in the Bronze Age, too. For similar reasons cushion-shaped mace-heads, represented by three examples in our area, cannot be accepted as certainly neolithic in age.

Bronze Age. It is first in the Early Bronze Age that connected finds clearly attest human settlement in Strathmore, along the Tay estuary and in northern Fife. The period is conventionally taken as beginning with the

arrival in Britain of the round-headed Beaker folk coming from the Continent. The characteristic vase that gives its name to the invaders is represented in 20 burials in our area. It is now admitted that the Beaker folk reached Britain in two quite distinct waves, each doubtless composite. The first wave is characterized by B beakers, the profiles of which form a continuous S curve. Such are well represented on both sides of the Tay estuary; cord-ornamented beakers from Law Park, St. Andrews, Tentsmuir, and Castle Huntly are related on the one hand to some from northern Holland, on the other to well-known examples from the Lothians, Peeblesshire, and south-western Scotland. In Strathmore beakers of all types are rare in comparison with food-vessels and most belong to the AC family. Their distribution is conspicuously inland, not coastal. Mrs Stewart (Mitchell) holds that their makers came by land either from Aberdeenshire or from south of the Forth. The striking similarity of the AC beaker from Greenhill, Balmerino, to one from Midlothian enhances the probability of the second alternative.

Food-vessels are typical of a second culture generally later than the Beaker-cultures, but certainly overlapping with them. This overlap may be documented from local material. A beaker from Idvies, Angus, has an internally bevelled rim, proper to food-vessels, and accompanied a cremation interment. The jet necklace associated with the beaker at Law Park agrees precisely with those associated with food-vessels in no less than six instances. The region here surveyed boasts at least 30 food-vessels as against 20 beakers, though, owing to their much softer clay, these vases have a much poorer chance of survival. Of the two groups into which it is now customary to divide food-vessels, five might with some confidence be ascribed to the Yorkshire series (with grooved shoulder) and nine to the Irish family. A double groove spanned by pierced stop-ridges is an interesting feature in the food-vessel from Sandyford, Kirriemuir.

Apart from a few camping places on Tentsmuir, habitation sites of the Bronze Age are unknown. The vessels described all come from graves. The rite was either contracted burial, usually in a short cist, or cremation. Beakers generally accompany inhumations, but at Idvies, and perhaps at Collessie, were associated with burnt bones. Many food-vessels, too, have been found with unburnt skeletons in cists, but rather more frequently accompany cremations.

Three burial cairns deserve especial mention. That at Collessie was originally 40 ft. high and 120 ft. in diameter. An irregular semicircle of slabs on edge, open to the west, was buried under the cairn which was erected on artificially levelled ground covered with a bed of laid clay. A central cist on the ground contained a skeleton and an AC beaker; a pit dug into virgin soil to the west contained a BC beaker, and a second pit, still farther west of the centre, held cremated bones and a triangular knife-dagger with gold-capped pommel. A cairn at Greenhill overlooking the Tay above Balmerino was 50 ft. in diameter and sustained by a peristalith. Near the centre it covered an upright stone standing 3½ ft. high and, immediately to the west of this, an empty cist. Nearer the circumference were deposits of cremated bones, parts of two "jet" necklaces and seven food-vessels, two of which filled with cremated bones had been covered with a wooden lid. In Angus a great cairn on the Sidlaws above Wester Mains of Auchterhouse covered a double cist containing cremated remains and a bronze dagger with a horn

hilt. The cist was buried in a mound of fine black earth, 20 ft. in diameter, and delimited by a ring of boulders. This in turn was covered by a pyramidal cairn supported by a peristalith, 62 ft. in diameter. In other parts of Scotland beaker and food-vessel interments have been found in stone circles. No such association is attested here, and in fact very few stone circles survive. Stones at the smithy at the foot of Pitscandly Hill on the old road from Forfar to Brechin probably represent the remains of such a circle.

Beyond clay urns, the furniture rescued from our Bronze Age graves is relatively poor. But our area has yielded no less than eight "jet" necklaces, one composed of disc beads, the remainder of several strings of barrel beads separated by decorated spacer-plates. An amber bead, now lost, is reported to have been found in a cist near Dundee. Of metal we have flat bronze rivetted daggers from Collessie and Linlathen, and a more advanced weapon with a midrib and hilt of ox-horn from the cairn at Auchterhouse (p. 59). The latter weapon is already a type proper to the early Middle Bronze Age and the gold mount of the Collessie blade agrees precisely with that attached to a Middle Bronze Age blade from Arran. As we shall find that a Middle Bronze Age as a distinct typological period cannot be distinguished in our area, we have to reckon with the possibility that the beaker-food vessel phase in the funerary record covers both the Early and Middle Bronze Ages as defined by hoards south of the Forth.

With this reservation we may supplement the funerary record by a reference to metal objects of Early Bronze Age type collected stray in the Dundee district. It has yielded 11 flat axes (five from Angus and five from the vicinity of Perth) and seven rivetted knife daggers, including the three grave-finds already mentioned.

As in the rest of Scotland north of the Forth, developed types such as define the Middle Bronze Age in England are represented only by a few strays. No rapiers have been found north of the Tay at all, but one from Dunshelt, Auchtermuchty, falls just within the southern border of our map. I know only 4 winged axes, 4 palstaves, and 2 spear-heads with loops on the socket from the area under review.

Late Bronze Age types on the other hand are relatively numerous and bear witness not only to an increased population but also to renewed intercourse with the Continent, England, and Ireland. Hoards indicate the role of Strathmore as an artery of commerce. From the list recently published by Mr Henderson I can cite 15 socketted axes and 20 leaf-shaped swords. Five swords from the Tay below Perth may point to the estuary as a port of entry for this exotic type. That from Migdrum I. is the only U type sword from Scotland. The rest belong to the V type—a later and distinctively Britannico-Hibernian derivative of the more Continental U type. Of the axes, one from Strathmore is explicitly connected with Fox's "Yorkshire" group, while another is no less distinctively Hibernian. The remaining tools and weapons belong to the usual Britannico-Hibernian repertory, though the great spear-head with lunate openings in the blade from Denhead deserves mention as an unusually fine specimen of this well-known type. In the Balmashanner hoard Irish gold is associated with Baltic amber and bracelets with asymmetrically expanding ends that Miss Benton claims as a Central European form.

While the Late Bronze Age bronze implements suffice to mark a distinct typological period, the increase in population since the earlier phase of the

Bronze Age is better illustrated by burials. These now take the form of cremation interments in Cinerary Urns, seldom enclosed in a cist or surrounded by a circle or covered by a cairn. Such coarse unprotected vessels are peculiarly liable to unrecorded destruction (at many places the Six Inch Ordnance Maps mark " many urns found here "), so that statistics of their numbers and distribution would give no accurate idea of the density of population or areas of settlement. In Fife and along the Tay such cremation interments are regularly grouped in cemeteries or " urnfields." Thus at Law Park, St. Andrews, there were at least 20 urns, at Breckmont Mill, Leuchars, 13, at Carphin House, 22. At Carphin House 15 urns were arranged in a row. At Westwood, Newport, the urns formed a circle. The groups reported from Strathmore are smaller. At Gilchorn, Arbroath, there were six, all under a cairn.

It is perhaps needless to invoke an invasion by " urnfield folk " to explain this grouping of burials. Grouped burials have already been mentioned in Fife in the previous phase at Balmerino and Collessie. In other cases, too, it looks as if the urn burials may have been planted in a cemetery used in the earlier Bronze Age. So at Law Park the urnfield was in the same field as the cists containing the beakers previously mentioned. At the foot of Tealing Hill two Cinerary Urns (of the Enlarged Food-vessels form) were found directly over, but 3 ft. above a cist containing an unburnt skeleton. The urnfields contain urns of all types—enlarged food-vessels and their derivatives the encrusted urns and members of the overhanging rim family from early types with well-marked neck and shoulder to the supposedly late cordoned urns.

Urn-burials seldom contain relics, but those recovered are important. From Mill o' Marcus comes a segmented bead of fayence diagnosed as Egyptian by Beck and Stone, though admittedly different from the type so freely imported into Wiltshire about 1400 B.C. An urn at Gilchorn contained a small bronze blade with two notches at the base and a midrib on one face only, curiously like a type current in the Copper Age of southern Spain and Portugal that was imported to Denmark while that country was still in the Stone Age.

Making due allowance for the destruction wrought by intensive agriculture, for the inertia of collectors in the region, and for the appalling lack of systematic excavation, the Dundee district and Strathmore do not seem to have been at all thickly populated in the Bronze Age. Presumably the most fertile lands were too thickly wooded and too marshy for tillage or pasture till the introduction of economical iron-working made durable metal tools cheap enough to be available to every farmer and pastoralist.

Iron Age. At least 30 forts and no less than 13 " earth-houses " are known in our area. Of course, not all of these need be contemporary ; the Iron Age lasts from 200 B.C. to any date you like in the post-Roman Dark Ages. So few forts have, however, been excavated scientifically that they can only be classified on the basis of their visible external features. Adequate data for assigning any particular class to one period rather than another within the vague Iron Age are still missing.

The earliest dateable relic of the Iron Age known from Scotland is a brooch (fibula) of La Tène I. type found in the fort on Castle Law, overlooking the Tay estuary above Abernethy. This sort of brooch had been

elaborated among the Celtic peoples of Central Europe and Eastern Gaul during the 4th and 3rd centuries B.C. and was superseded by a new fashion about 200 B.C. Our specimen is more like some from Switzerland than any English brooch. The same fort yielded also some corroded tools and weapons of iron, a very thick runner ring of jet (lignite), a grooved bracelet of the same material, a bronze finger ring, and a ring-head pin of iron—all objects appropriate to the Celtic La Tène cultures of the Continent, with no sort of roots in the local Bronze Age tradition. The fort itself is a mature example of a system of fortification developed on the Continent. The summit of the law is defended by two walls of similar construction. The inner rampart is 18 to 25 ft. thick and faced with masonry walls inside and out. In the outer face a double row of rectangular beam-holes is still visible. They once held timber beams which ran transversely through the wall and tied the two faces together. The space between the faces was filled with rubble and timbers. Such a rampart is often termed a Gallic wall and approximates in structure to what Caesar describes in his Commentaries on the Gallic war. A fort on a hill above Forgandenny a little further west is similarly defended.

Experiment has shown that a Gallic wall can be set on fire and that the heat generated in its combustion suffices to melt the rubble of the core if the rocks are not too refractory. It is therefore likely that the so-called vitrified forts, characterized by the presence of masses of stone fused together in the wall-cores, are just burned Gallic forts and were erected at the same period. At least five forts in our area have partially vitrified walls, but only Finavon, near Forfar, has been explored by modern methods. The citadel takes the form of a trapeze-shaped enclosure on the top of an uneven hill. The long north and south walls run dead straight for 300-400 ft. regardless of the natural contours of the summit. The actual walls, now buried in debris, are 20 ft. thick, faced on both sides with superb masonry still standing in places 8 ft. high, and must originally have attained the imposing elevation of 16 ft. The blocks of vitrified material now visible have all fallen from the higher courses of the ramparts, but excavation disclosed a few blocks probably *in situ* in the core near the top of the surviving masonry. A well at the east end (now exposed), cut through the living rock to a depth of 20 ft., yields no water. It had been filled up as useless by the fort's occupants, who then dug the well at the west end (which contained water last century till a farmer filled it in) and extended the defences to incorporate it. Very coarse pottery quite unlike any Bronze Age fabric, flint scrapers, spindle whorls, crucibles, scraps of iron were recovered, but the only indications of date were a thick "jet" runner ring, like that from Abernethy, and the absence of Roman pottery.

By analogy the huge hill-top town or *oppidum* on Turin Hill, covering 14 acres, should also be pre-Roman. Its defences, apparently a wall of the terraces type such as is seen at Stradonitz in Bohemia and in Scotland in the pre-Roman fort on Burnswark, are quite unlike those of Abernethy and Finavon and slavishly follow the contours of the hill. Within the original enceinte are later structures in a much better state of preservation—notably the ring-fort noticed below.

Three small ring-forts with stone walls 12 ft. thick enclosing an area 27 ft. in diameter—Hurley Hawkin, St. Bride's Ring, and the Laws, Monifieth—have been called brochs. They reveal, however, no trace of the guard-cell

and spiral intramural staircase that constitute the sole reliable diagnostic symptoms of a genuine broch. I believe these forts, together with one in the enceinte on Turin Hill, another on Pitscandly Hill, etc., should be connected with a well-known series of stone ring-forts in central Perthshire that can be traced along Loch Awe to the west coast in Argyll, and that resemble in a general way Irish cashels. The " broch " near Monifieth stands within a complex system of masonry walls partially vitrified. Somewhere at the site an early ring head pin was found. The broch may here be an intruder in an earlier work as is the ring-fort on Turin Hill.

An earth-house (also called a *weem*, and in Ireland and France a *souterrain*) is a gallery built in an excavated trench generally walled with unquarried boulders and roofed with large lintel stones covered over with earth. All must have been attached to steadings or small hamlets built above ground, but these have not survived. The group of 13 in our area north of the Tay constitutes one of the largest concentrations of earth-houses in Scotland. At West Grange of Conan a corbelled beehive-cell, 11 ft. in diameter and 7½ ft. high but also subterranean, opens off the main gallery just as at Castle Law, Glencorse, and at Chapel Euny in Cornwall. Cup-and-ring marked stones are included in conspicuous positions in the walls at Pitcur and Tealing ; a serpent is carved on a lintel at Barns of Airlie. As such markings are generally Bronze Age in date, these carved stones may have been re-used in making the earth houses. Fragments of *terra sigillata*, including some first century pieces from West Grange of Conan, show that these earth-houses were occupied during the Roman period.

Roman Period. In 83 A.D. the legions under Agricola penetrated Strathmore, and it was perhaps in this region that the Roman general won his famous victory at Mons Graupius. As monuments of their mastery over Strathmore the Romans have left a line of camps beginning at Inchtuthil, near Perth. None of those in Strathmore has been excavated and the duration of Roman control over this area is still uncertain.

Dark Ages. Hill forts were not necessarily abandoned when the Romans departed. Indeed, I would attribute to the post-Roman period the ring-forts mentioned on p. 62 and also the erection of a souterrain in the fort at Dunsinane ; for this is a distinctly Irish feature, like the ring-forts. Both may be monuments of an early infiltration of Scotti into Pictavia. Of the traditional Dalriadic eponyms, Loarn (who gives his name to Lorne) had a brother Angus, Comgall (Connell) a brother Gabran. The name of the first may survive in Angus, that of Gabran in Gowrie ; Gabran is indeed said to have been defeated by Brude, King of the Picts. But the period after 400 A.D. is the least known in Scottish prehistory, the darkness of which is only emphasized by these tantalizing references in late and suspect chronicles.

In Angus and Perthshire its obscurity is to some extent relieved by the so-called Pictish symbol stones and cross slabs, peculiar to the north and east of Scotland and represented by a magnificent group of over 55 monuments in our area. The former monuments bear two or more of 14 symbols, including geometrical and compass-drawn figures (the Z and V rod, the, crescent, conjoined circles, . . .), representations of mirror, comb, hammer, and anvil, and stylized animals—serpent, wolf, and a fantastic beast resembling an elephant. These are generally incised on natural boulders, rude standing stones and cave walls, but occur also traced on bone or metalwork. Few

examples of symbols engraved alone occur in our province. Here they are more often carved on dressed slabs bearing on one side a cross and combined with Irish interlacing work and sculptures in low relief depicting ecclesiastics, warriors, centaurs, strange beasts, biblical and hagiographic scenes, battles, and hunts. Frequent occurrence in churchyards suggests, not necessarily use as gravestones, but at least a regular association with Christian cult. Yet a stone at Meigle seems to represent the Celtic god, Kernunus.

The engraved symbol-stones are generally supposed to be purely Pictish and have been dated as early as the third century. But even in them, Christian symbolism has been detected by many authorities. The mirror and comb are common on pagan Roman stones, but also on early Christian monuments; the form of our mirror is, however, La Tène. On the cross-slabs the symbols are combined with explicitly Irish ritual and artistic traditions and perhaps also motives borrowed from Northumbria. But even on them the style of the figural carvings is peculiar and distinctive—presumably Pictish. A date in the eighth century for the main group to be visited by the Association is not improbable, but some must be later and substantially lower dates have been seriously advanced. Dating depends, however, on minute stylistic comparisons which cannot be discussed here.

VIII.

MEDIAEVAL AND RENAISSANCE ARCHITECTURE IN THE DUNDEE DISTRICT

BY

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(a) Ecclesiastical.

The cross-slab symbols mentioned at the end of the previous article have been assigned to the period 800-1000; to the eleventh century and the early part of the twelfth belongs another type, similar in design but without the symbols, and sometimes displaying a vine-scroll beside the zoomorphic ornament. A large collection of these later cross-slabs is to be found in the Cathedral Museum of St. Andrews. But no vestige of the dark little churches beside which these stones were erected is to be found in this part of Scotland. At Brechin, however, the builders of the thirteenth century cathedral spared the round tower, over 86 feet high, which the Celtic monks had erected after a disastrous raid at the beginning of the eleventh century. The narrow doorway, six and a half feet above the ground, with its semicircular head scooped out of a single stone, the internal string courses which supported the floors of the seven rooms into which the tower was divided, the small windows with inclined jambs which lighted the lower rooms, the four rectangular windows under the parapet facing the four cardinal points—are all features which suggest an Irish original. A similar round tower, about 72 feet high, stands at Abernethy. The upper portion, however, seems to have been rebuilt, for the four round-headed windows below the parapet are distinctly Norman in character.

With the exception of these towers, the oldest ecclesiastical buildings in the neighbourhood of Dundee date from the reign of David I. (1124-53), the half-English monarch, educated at the court of a Norman king, who began a peaceful Norman Conquest of Scotland which led to the establishment of the new religious orders either in the old Celtic monasteries or in completely new foundations, and to the consequent displacement of Celtic monks by Normans or Englishmen. An Augustinian priory, for example, was founded at Restennet, Augustinian canons were introduced into St. Andrew Cathedral, and though the Culdees—who may be called Celtic Canons Regular—were allowed to remain at Brechin, their church became the cathedral of a new diocese. The policy of David I. was continued by his grandsons, Malcolm IV. (1153-65), who founded the Cistercian monastery of Coupar Angus in 1164, and William the Lion (1165-1214), who in 1175 founded a great Benedictine Abbey at Arbroath. A third grandson, David Earl of Huntingdon, transplanted to Newburgh the old Celtic monastery of Lindores, now reorganised as a

Benedictine abbey. The Cistercian abbey of Balmerino was founded by Ermengarde, the widow of William the Lion, and her son, Alexander II., in 1229.

Of these "pious edifications" only tantalising fragments remain—at Coupar Angus the gatehouse and the bases of some of the nave piers, at Lindores the rubble core of the walls of church and cloister, while at Balmerino the abbey church has been reduced to its foundations, though the pillared vestibule of a fifteenth century chapter house, and the roofless shell of the chapter-house itself, have been preserved. But enough remains to show that there had been a clean break with Celtic tradition, and that the craftsmen who at St. Andrews and St. Vigeans used the Celtic cross-slabs as building materials looked to England for their inspiration and followed the English architectural fashions of the day before yesterday. Thus the square, plain, slightly tapering twelfth century tower of Restennet, with its traces of long and short work, its windows with inclined jambs, and the semicircular arch, scooped out of a stone slab laid on edge, which surmounts its south doorway, is reminiscent of the Romanesque churches that were built in northern England on the eve of, or immediately after, the Norman Conquest. Rounded window heads carved out of the lintel and other archaic features appear in the unadorned but strangely impressive church and tower of St. Regulus at St. Andrews, which Bishop Robert built in the second quarter of the twelfth century. He took as his model, it would appear, the early twelfth century church of Wharram-le-Street in Yorkshire.

Of the smaller Norman churches little is left in Angus—a few courses of masonry at St. Vigeans, a characteristic window and chancel arch at Lundie —but in Fife, Leuchars Church retains its richly ornamented late Norman apse and chancel.

The outstanding example of Transitional and Early English work in the area was St. Andrews Cathedral, begun in 1160 and completed, as a great cruciform church, measuring 391 feet from east to west, about a hundred years later. The nave was shortened by two bays in the time of Bishop William Wishart (1273-79), who erected the present west front and substituted pointed windows for the Transitional windows in the south-western bays of the nave. The upper part of the west front, however, was reconstructed at the end of the fourteenth century, to which period also belong the east window which replaces two of the original three rows of Transitional windows which pierced the east gable. Unfortunately, beyond the bases of walls and piers nothing is left of the church but the east gable, the west wall of the south transept, the south wall of the nave, and part of the west front. A doorway and its two flanking windows remain to give one some idea of the pure, serene beauty of the thirteenth century chapter-house, but of the other conventual buildings only the foundations are left, encased in the red sandstone of late nineteenth century restorations.

At Arbroath Abbey, "once of great extent and stupendous magnificence," the west front with the tall lancets of the twin towers and its pillared gallery above the deep-set, round-arched doorway is almost intact; so is the south transept, with its strange mixture of architectural styles—round-headed arches above pointed arches—great soaring lancet windows in its western wall. As at St. Andrews, the choir terminated in an aisleless presbytery, much of which has been preserved, and though only an angle of the chapter-house

is left, and the very foundations of other conventual buildings destroyed, Arbroath has been fortunate enough to retain, embedded in a later medieval building, one of the earliest examples of domestic architecture in Scotland, the thirteenth century Abbot's Hall. At Restennet, too, the twelfth century church was demolished, and the west tower became the central tower of a long, narrow church in the Early English style, without towers or transepts. Of the thirteenth century church the roofless choir and the foundations of the nave still remain.

When Brechin Cathedral was completed in the thirteenth century it consisted of an unusually beautiful aisleless choir, eighty-four feet long, and a nave of five bays, with clerestory windows, but without a triforium gallery. The massive square south-western tower which balances the older round tower on the other side of the deeply-recessed Early English doorway was probably completed, except for the spire, in the third quarter of the fourteenth century. After the Reformation the choir was allowed to fall into ruin, but the nave was preserved for use as a parish church. Like many other churches in Scotland, Brechin suffered less from the seventeenth century reformers than from the early nineteenth century restorers. Most of this mischief has been undone in our time, and Brechin survives to show that the medieval craftsman could make a comparatively small building carry an impression of spaciousness and calm dignity.

Though the thirteenth century saw the establishment of Franciscan convents in Dundee and St. Andrews and Dominican convents in Dundee and Perth, little remains of these foundations, and that little is much later than the thirteenth century. In Dundee we have the Howff, a sixteenth century graveyard which was originally a " place or yaird . . . occupyet by the Grey Cordeliar Freris." Little more is left of the parish churches built in the thirteenth century; the roofless, ivy-clad church of Abdie, near Newburgh, is almost the only example.

The death of Alexander III. in 1286 marks a break in the development of ecclesiastical architecture in Scotland. Not only had the impulse to found cathedrals and monasteries spent itself; the war with England, which dragged on for a quarter of a century after Bannockburn, left the country demoralised and impoverished. The architectural history of the fourteenth century is almost a complete blank; old churches might be destroyed in war—like St. Mary's, Dundee—but no new churches were built, though the Pends at St. Andrews and a similar great gatehouse at Arbroath now protected the entrance to Priory and Abbey. Not till the second decade of the fifteenth century did the erection of great churches recommence, and then, it should be noted, the builders no longer drew their inspiration from England. Looking sometimes to contemporary France, sometimes back to the older churches of their own country, they evolved a distinctive architectural idiom. Thus Holy Trinity Church, St. Andrews, though it is the restoration of a restoration, retains some of the original cylindrical piers and semicircular arches which testify to the fifteenth century architect's fondness for twelfth century forms. The semicircular arch appears again in the clerestory of the choir of St. John's Church at Perth, and in the doorway of St. Mary's Tower in Dundee. French influence is evident in the trigonal apse of St. Salvator's Chapel, built in 1450, and in the splendid canopied tomb of its founder, but

the sacrament house on the right of the tomb, the three trigonal arched doorways, and the massive buttresses which upheld the heavy barrel-vaulted roof and its covering of flagstones, are specially characteristic of the country and the period. The barrel vault has been replaced by a timber roof, but in the neighbouring chapel of the Blackfriars one can see the pointed barrel vault with ornamental ribs applied to it, built by craftsmen who had lost the art of constructing a true groined roof.

While the great thirteenth century churches were raised by some prince or prelate, most of the notable fifteenth century churches bear witness to the growing wealth and civic pride of the burghs. In St. Andrews, in Cupar, in Perth, in Dundee arose the western towers of great new churches, where the aisles in nave and transept were screened off to accommodate the multitude of chapels maintained by the piety of craft gilds or private families. Holy Trinity in St. Andrews was built in 1411, St. Michael's, in the neighbouring burgh of Cupar, in 1415. Of the latter only the western tower and three arches of the nave are left, but Perth has preserved and restored to much of its pristine beauty the church of St. John the Evangelist. Here, however, lack of funds forced the burgesses to modify their original plans, and so a dark, low-browed nave of five bays, the last part of the church to be built, leads to a lofty choir, with massive piers, great windows filled with curvelinear tracery, and a hammer-beam roof. Though one notices here the corbels which supported the rood loft and, in one of the four great piers supporting the tower, the door and stair communicating with it, the rood and rood screen themselves, with all the original woodwork, stained glass, and wall-paintings have vanished from St. John's as from all churches in our area. Only the little village church of Fowlis Easter retained till late in the nineteenth century its rood screen with carved wooden doors and painted panels of apostles and saints, and the great picture of the Crucifixion which surmounted it. The late nineteenth century restorers dismembered the screen but preserved the fragments; the doors have been fitted into a modern screen and the painted panels hung on the walls of the church.

Nowhere was the growth of civic pride more apparent than in Dundee itself, where the parish church belonged to the monastery of Lindores. In 1442 the burgesses agreed to relieve the Abbot of his obligation to maintain the choir in good repair, and proceeded to build a great cruciform church, which they completed about half a century later by the erection of the massive western tower 165 feet high—that Old Steeple which is one of the glories of Scottish architecture. But of the original church there have survived only part of the north wall of the nave, including the north doorway, and a few late medieval tombstones which are preserved in Dudhope Museum. The nave was battered down by the guns of an English fleet in 1547, the choir and transepts, which in the economical Scottish fashion had been divided between two congregations, were destroyed by fire in 1841.

Apart from Fowlis Easter, the most interesting of the smaller parish churches in this area is St. Vigeans—which, though it contains some Norman masonry and a multitude of Celtic cross-slabs, is substantially a late fifteenth century structure, with the cylindrical piers and circular arches which repeat an earlier fashion. But the chapel of the suppressed college of St. Leonard in St. Andrews, with its square-headed mullioned windows, is one of the rare

Scottish experiments in the Perpendicular style, and it was not built till the early years of the sixteenth century.

With the Reformation—all the more violent because it was long delayed—the interest shifts from ecclesiastical to secular architecture. Though the Reformation destroyed the monasteries it spared the parish churches—their destruction was delayed till the end of the eighteenth century or later—but it left only the shells of the buildings—stained glass, mural paintings, statues, rood screens, and choir stalls—all were destroyed. Large churches, like St. John's in Perth or St. Mary's in Dundee, were partitioned off to accommodate two, three, or four separate congregations; large and small churches alike were darkened by deep lofts or galleries. But here and there some example of honest craftsmanship—the late sixteenth century pulpit in St. Salvator's Chapel, the ornate seventeenth century spire of St. Michael's, in Cupar, shows that the love of beauty had not wholly died out of the Scottish Church. A more ambitious attempt to recover a lost architectural tradition can be seen in the curious imitation medieval church built at Dairsie in 1637.

(b) Secular Architecture.

The sixteenth century Scottish castle bore little resemblance to its twelfth century prototype. This was a mote and bailey castle, similar to those which were erected in England immediately after the conquest, a structure of timber planted on a mound and encircled by a palisade. The mound might be natural, as at Dundee, where a little eminence beside the river, the original Celtic *dun*, became the Castlehill of later medieval times. The timber superstructures have long since been swept away, but the mote itself can still be distinguished at Leuchars and at Edzell.

The mote and bailey castle remained the commonest type of Scottish castle down to the end of the thirteenth century. Only here and there was it replaced by the enceinte castle, with thick stone curtain walls and massive flanking towers at the angle. At Kinclaven, near the junction of the Tay and the Isla, the curtain walls of a castle of this type are still standing, though the angle towers have disappeared, and there may be fragments of a thirteenth century wall of enceinte in Redcastle on Lunan Bay, which is mainly a fifteenth century structure.

The War of Independence affected secular architecture as it had done ecclesiastical architecture—directly by the destruction of existing buildings, indirectly by the impoverishment of the country. The Castle of Dundee, thrice occupied by English troops, was demolished by the command of Robert the Bruce and never rebuilt. It is significant that there are few examples of fourteenth century castles in our area, and that the late fourteenth and early fifteenth century castle is a modest structure, a single tower forming one side of a courtyard, the other three sides of which were enclosed by a barmekin—a high stone wall. The tower, which was square in plan, rose sheer to a projecting parapet supported by corbels. A yett or grille of wrought iron and a stout wooden door closed a single entrance. Within, the principal apartment, the hall, was on the first floor, above the vaulted basement containing the kitchen and storerooms. Access from the hall to the basement and the upper floors was provided by a narrow turnpike stairway; another stair led from

the hall to the wine cellar beneath, which could not be entered from the basement. Dungeon-like bedchambers were constructed in the thickness of the walls.

About the middle of the fifteenth century the square plan was superseded by the L shaped plan—the tower was now built with a wing, projecting from it at right angles, the lower part of which often contain a broad scale and platt staircase leading to the hall, while the upper rooms were used as bedchambers. This addition strengthened the castle against attack, as it commanded one and sometimes two faces of the tower, and protected the entrance doorway, which was usually placed in the re-entrant angle. The fifteenth century castle of Affleck is one of the earliest, as it is one of the best preserved, of those L towers in the neighbourhood of Dundee. Here, however, the wing, which contains on one floor an oratory and on another a garderobe with a loophole commanding a view of the hall, projects only a few feet from the front of the main building.

Castles after the pattern of these fifteenth century square or L shaped towers continued to be erected all over Scotland down to the second half of the seventeenth century. They can be counted by the dozen in the neighbourhood of Dundee, sometimes, as at Parbroath in North Fife, reduced to a fragment of masonry smaller than the castle dovecote, sometimes, like Castle Huntly in the Carse of Gowrie or Kinnaird Castle in Angus, surviving in the substructure of a grandiose " Scottish baronial " pile, sometimes, like Broughty Castle, restored so thoroughly as to be a nineteenth century copy of a fifteenth century original. Some, however, like Balvaird Castle near Abernethy and Scotstarvit Tower near Cupar, though uninhabited, are in perfect preservation.

Most of them are comparatively small; if we look for their English equivalent we shall find it in the fortified manor house rather than in the great castle like Warkworth or Warwick. On a much larger scale, however, and built to a different plan, is St. Andrews Castle, the palace of the Bishops —after 1472 the Archbishops—of St. Andrews. The original early thirteenth century castle built by Bishop Roger on the edge of the Scores—the scaurs or cliffs which overlook the bay—was twice destroyed and twice rebuilt in the course of the fourteenth century. In the late fourteenth century castle a cobbled courtyard, pentagonal in plan, was surrounded by a curtain wall with a square tower at each angle. Access to the interior of the castle was obtained by a vaulted passage in the base of the South, or Fore, Tower. It was blocked up in the sixteenth century, and a new entrance made between the Fore Tower and the vanished South-West Tower, but one of the *rainures* through which the drawbridge gaffs projected can still be distinguished. In the first half of the sixteenth century the towers were rebuilt and joined to one another by a range of stone buildings, continuous but for a gap on the western side, including the chapel, the great hall, and the stables. The new buildings were badly damaged in a bombardment by a French fleet in the summer of 1547. The existing facade, with its renaissance details and heraldic panels, is the work of Archbishop Hamilton (1550-71), the last Catholic Archbishop of St. Andrews.

That the Reformation should have given a great impetus to the building of castles is easily understood. All but the merest fraction of the lands and revenues of the Catholic Church, estimated at a third to a half of the total wealth of the country, passed into secular hands. The old families, newly

enriched, added a wing to the old tower or carried it up a storey or two higher; the new families signalised their accession to the ranks of the lesser gentry by building a new tower. Built of grey or reddish stone with slate or stone flagged roofs, these late sixteenth and early seventeenth century towers seem grim and comfortless beside the many-windowed brick or half-timbered manor houses of Elizabethan or Jacobean England. But though in a lawless and ill-regulated country some attention had still to be paid to security, these towers were designed as dwelling-places rather than as fortresses. They are often placed, like Mains Castle, on the outskirts of Dundee, in some pleasant, sheltered hollow. Sometimes the projecting parapet with its supporting corbels disappears, or is retained as a purely ornamental feature. Sometimes, as at Invermark Castle in Glenesk, angle turrets are substituted, sometimes, as at Claypots near Dundee, where, however, there is a short length of parapet, additional accommodation is secured by making square upper storeys which oversail the round towers from which they spring. The monograms and emblems on skew-put and pediment, the heraldic panels over the entrance door furnish additional evidence that security was not the only consideration in the minds of the builders.

Side by side with the towers appear structures which proclaim themselves to be less castle than mansion house, with panelled walls and plaster ceilings, elaborately decorated, sometimes having on the upper floor a long, narrow gallery, with a curved roof, lined with wooden boards, on which are painted allegorical figures and coats of arms. Such a painted timber ceiling, carefully restored by Sir Robert Lorimer, can be seen at Earlshall, near Leuchars, in the seventeenth century mansion house or hall which confronts the sixteenth century tower on the opposite side of the courtyard. Another, painted with heraldic designs and much decayed, exists at Collarnie Castle in the same county. Conversion first into a cotton mill, then into a barracks, has not altogether obliterated the external features of Dudhope Castle, in Dundee, built in 1600. In its original form the building was a storey lower than at present; and it enclosed two sides of a courtyard, the other two sides of which were formed by a stone wall which has disappeared. But the two drum towers that flank the pended entrance, and the three round towers at the angles with their conical slate roofs, even now give it something of the air of the Château of Loches in Touraine. The most interesting castles of this latest period, however, are Edzell and Glamis. At Edzell the architect has incorporated the massive early sixteenth century tower into the Renaissance facade of his late sixteenth century mansion house, the dilapidated buildings of which enclose the courtyard on two sides. These can be matched elsewhere; what is unique in Scotland is the pleasaunce, with its turreted summerhouse, and its charmingly designed garden wall decorated with heraldic devices and with panels representing planetary deities, the liberal arts, and the cardinal virtues, copied by a local mason from some German "Liber Amicorum."

"The house from the height of it," said the poet Gray, "the many towers, the spread of its wings, has really a very singular and striking appearance, like nothing I ever saw." This was while "the huge old towers of Glamis, 'whose birth tradition knows not,' showed its lordly head above seven circles of defensive boundaries"; before the too enthusiastic landscape gardener "had the cruelty to render the splendid old mansion . . . more *parkish*, as

he was pleased to call it, to raze all those exterior defences, and bring his mean and paltry gravel walk up to the very door," before, too, the high-pitched roofs and crowstepped gables had been removed from the wings of the castle.

The nucleus of Glamis Castle was the usual massive square tower with the projecting wing, or jamb. Its walls were ten feet thick, and three at least of its four stories were vaulted. At the end of the sixteenth century Patrick 9th Lord Glamis (1576-1615) added three more stories to the tower, placed a round tower containing a broad turnpike stair in the re-entrant angle, and built the south-west wing. His son John (1615-47), the tenth Lord, remodelled the interior of the original great hall, and constructed the decorated plaster ceiling which is one of the glories of the castle. Patrick, the eleventh Lord (1647-95), added the north-west wing and the chapel.

"It rises proudly with a cluster of hanging towers." The visitor cannot but be impressed, as Gray was, by the stark grandeur of the cliff-like walls, broken here and there by medallion or heraldic panel, sweeping up to expand into that fantastic cluster of overhanging turrets with high-pitched, pointed roofs, which reminds one not of seventeenth century England but of France, of the medley of towers and arches and pinnacles which crowns the desolate splendour of Chambord.

The existing "Bonnie Dundee," the "Fair City," and the other burghs in the area, for all their long history, are substantially products of the utilitarian nineteenth century. The almost universal use of stone and slate as building materials, the fact that the bulk of the population is housed in tenements—blocks of flats subdivided into two or three rooms—make them seem even more grim and austere than their English counterparts. Though Cupar retains its mercat cross, St. Andrews its West Port, a noble sixteenth century gateway, and Dundee its more dilapidated Cowgate Port, they possess nothing corresponding to the medieval or renaissance guildhalls which we find in English towns of the same antiquity. Dundee did, indeed, boast a Town Hall designed by William Adam, father of the more famous Robert, but this unique example of the work of the elder Adam was destroyed by an iconoclastic Town Council in 1931. Little, too, is left of the original collegiate buildings of St. Andrews except those which line two sides of the charming quadrangle of St. Mary's College. The range on the west side of the quadrangle, built, it is said, by the French workmen who had been employed at Falkland Palace and restored in 1621, retains few of its original features except the homely little College Hall; while the most attractive part of the early seventeenth century library on the north side is the upper hall with its eighteenth century woodwork. St. Andrews, however, unlike most of the other towns in the area, contains numerous examples of sixteenth and seventeenth century dwelling-houses. They cluster thick at the east end of South Street—manses of cathedral dignitaries like Dean's Court, town houses of country lairds like No. 42 or 46 South Street, houses of wealthy merchants where a queen would not disdain to live, like "Queen Mary's"—now the library of St. Leonard's School.

But St. Andrews and Cupar, like the villages of North Fife, owe much of their charm to the small, seemly, unpretentious houses built of honey-coloured stone, roofed with red tiles mellowed by a century's rains. One sees them everywhere in North Fife; they seem in perfect keeping with their natural

background, like the reed-thatched cottages in the Carse of Gowrie. Less attractive, but equally in accord with their background, are the sturdy cottages and farmhouses, roofed with slabs of gray stone, scattered about the unsmiling Angus landscape. But here, as in so many parts of rural England, the newer houses seem to be at odds with their surroundings: in a country with abundance of good building stone the bricklayer has been allowed to oust the mason, and cold, blue slate replaces the red tiles of Fife, the thatch of the Carse, and the stone slabs of Angus.

Printed in England at The Ballantyne Press
Spottiswoode, Ballantyne & Co. Ltd.
Colchester, London & Eton

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

(Founded, 1831. Incorporated by Royal Charter, 1928)

A SCIENTIFIC SURVEY OF

DUNDEE AND DISTRICT

PREPARED FOR
THE DUNDEE MEETING 1939

BY VARIOUS AUTHORS

Edited by
R. L. MACKIE, M.A., B.Litt.
Training College, Dundee

These surveys, since their initiation in 1932, have been issued to members attending the Meetings, and have subsequently been included in the Annual Reports. The intention in future is to include the survey for the forthcoming meeting in the July issue of 'The Advancement of Science' preceding such meeting ; but no survey will be issued in 1940. Meanwhile the Dundee Survey is continued here from Nos. 1 and 2 of 'The Advancement of Science,' and is concluded.

CONTENTS

IX.

THE ECONOMIC HISTORY OF DUNDEE

1.—UP TO 1760

BY

S. G. E. LYTHE, M.A., School of Economics, Dundee.

"Simplicity is the outcome of technical subtlety; it is the goal, not the starting point. As we go backwards the familiar outlines become blurred; the ideas become fluid, and instead of the simple we find the indefinite." These words of Maitland appear as the prologue to one of the outstanding contributions to Scottish economic history, but they apply with equal force to all economic history. The people of any town or country have an economic history going back far beyond historical record, back to the first settlement of men, but in the early phases much is vague and little definite. Only in the later phases, with regional and occupational specialisation, can history be written in firm strokes and with any approach to exactitude. This uncertainty about the earlier phases can, however, be reduced by limiting the study to a small area where geographical factors such as relief and climate have exerted a continuous though often diminishing influence on human activities.

The original settlement of Dundee was probably a fishing hamlet in the sheltered bay between St. Nicholas Craig and the Castlehill, which, before comparatively recent reclamation work, stood out into the Tay. The purpose of this essay is to trace the evolution of the town from the primitive subsistence economy of these fishers to the capitalistic industrial organisation of the present day with its heavy reliance on world commerce. For lack of material the study cannot begin earlier than the 12th century. About that time urban development was proceeding rapidly throughout Western Europe, and it seems that in Scotland as in most other countries the main impulse came from commerce. This early trade in Scotland was conducted to a great extent by foreigners, especially Flemings, who settled in large numbers in Fife and Angus in the 12th century, and in the following century the town of Bruges had a street called "Scotland."

In the charters of David I. certain towns are spoken of as "burgo meo," but the custom of granting individual burghal charters was not common until the reign of William the Lyon (1165–1214), and it was in his reign that Dundee and the neighbouring settlements of Forfar and Montrose were elevated to the rank of royal burghs. It is tempting to overstate the significance of such royal recognition and to give false value to the part of the burghs in the national economy. As late as the 15th century the burghs bore only one-fifth of the total national taxation. Specialisation by countrymen in agriculture and by townsmen in industry and commerce

was but dimly foreshadowed when Dundee and the neighbouring burghs acquired corporate status. Neither industry nor commerce sufficed to maintain their economy, for they were partly, perhaps mainly, agricultural communities, and this urban interest in agriculture could be seen in Dundee as recently as the time of the first Statistical Account. The countryside furnished most of the commodities of trade, indeed the original function of most burghs was the exchange or export of such rural produce.

For this function Dundee was well located. Far enough from the open sea to be safe from storms and piracy, the harbourage within the shelter of Castlehill was as safe as the mediaeval mariner could reasonably expect. The rich agricultural lands of the Carse of Gowrie and Strathmore lay within easy reach by land, whilst the two-mile ferry over the Tay touched the golden fringe of the "beggar's mantle." Little detailed information is available regarding the nature or magnitude of trade before the Wars of Independence. The close connection between Scotland and England at the time is reflected in King John's grant to the men of Dundee of freedom from toll and all other customs of the crown in England except in the city of London (1199). At that time, however, economic conditions in Scotland and in England were more alike than at any other period until modern times, and as early trade was mainly conditional on differences in economic development it is not surprising that Scotland's overseas trade was already orienting towards the industrially advanced regions of Flanders. The authors of "The Scottish Staple at Veere" have emphasised this; "The history of the organisation of Scottish trade with the Netherlands and its concentration in one town is in a large measure the history of Scotland's foreign commercial relations." The later development of Dundee's trade with the Baltic may be interpreted as a criticism of this sentence, but her trade in the 13th and 14th centuries reveals both Scotland's reliance on the Netherlands and the relative development of the two countries. Dundee was primarily an exporter of the products of the hinterland, hides and woolfells (Coupar Angus was one of the wool-producing houses on Pegolotti's list), and an importer of better-class fabrics, wines, spices, and confections for the nobles and the itinerant royal household. We may surmise that Dundee received raw materials from the Highlands and exported them both abroad and coastwise, though its part in the Highland trade was always rivalled by Perth, indeed, not until 1402 did Perth abandon its claim to a monopoly of the shipping in the Tay. Dundee had not yet attained its greatest relative importance. It was one of the seven burghs represented at Bruce's Parliament at Cambuskenneth, but its Great Customs in 1327 were substantially less than those of Berwick, Edinburgh, and Aberdeen.

The second quarter of the 16th century saw Dundee rise to the rank of second city in Scotland. To a special assessment in 1535 Edinburgh contributed £833, Dundee £321, and Aberdeen £315. Glasgow, which was ultimately to surpass all three, paid £67. Berwick, after changing hands several times, had eventually become part of England. Various economic factors contributed to this change in Dundee's place in the national economy, but the strategic consideration was possibly more influential. Miss Grant has observed that Edinburgh was unduly vulnerable to attacks from England and that this resulted in a shift of the economic centre of gravity across the Forth. Dundee might be sacked from the sea, but a landward attack was

unlikely. The town was still predominantly a trading centre. The Gild Merchant, after centuries of shadowy existence, finally assumed an easily recognisable form in the early 16th century. But a new element, industry, had entered the town's economy. According to Warden, some, if not all, of the Nine Incorporated Trades existed in the 14th century, but there is no evidence of incorporation until the early 1500's. The mere fact of incorporation implies a more whole-hearted attention to industry as a full-time occupation, whilst the conflict between the craftsmen and merchants, settled by the "Decree Arbitral" of 1527, reveals the growing strength of the industrial element. This duality of the town's economy puzzled Bishop Leslie: "Neither sal ye weil discerne quither thay be richer in outlandis geir (foreign ware) and merchandise, or in thair awne labour and industrie."

The industrial life of the town was based on textiles. "Dunde," wrote Boece, "quhair mony virtewus and lauborius pepill ar in, making of claith." There was already some localisation of industry in Scotland, and by the end of the 16th century Dundee was importing more dye-stuffs than nearly all the other burghs put together. In the "Compt Buik" of the Dundee merchant, David Wedderburne, there are frequent references to the export of "hemp clayth," "narrow blew clayth," and "lyning," but the mainstay of the industry was plaiding. The plaid was the prevailing costume for men of all but the highest ranks, and women of all ranks enveloped their heads in plaiden shrouds whenever they appeared in public. Burghal edicts in places such as Aberdeen attempted to maintain the aristocratic character of the Scottish merchant class by forbidding the wearing of plaids and bonnets, but both Town House and pulpit thundered in vain against these popular garments, both of which were Dundee specialities. Nor was the demand entirely domestic. "Claythe and plading" represented nearly 40 per cent. of all exports of Scottish manufacturers in the early 17th century. Dundee was already importing some textile raw materials, hemp, and lint from the Baltic, though the wool was still home produced.

As the 16th century went on both the King and the Convention of Royal Burghs sought to stimulate this native cloth industry. Its development in Dundee was due less to this intervention than to the ease with which raw materials and finished goods could move along existing land and sea trade routes,* for Dundee still stood out as an importing and distributing centre, and the "Compt Buik" and Shipping Lists furnish a very complete picture of the trading activities of the burgh. As early as 1487 Aberdonians were deploring the fact that the Danzig traders had deserted them for Dundee and Leith. They might have added that the reason for this desertion was that Danzig merchants had been paid in spurious money at Aberdeen. By the latter part of the 16th century Dundee had twenty to thirty ships in the Baltic trade, the majority of them trading mainly at Danzig. With great regularity Dundee imported from the Baltic cargoes of timber, iron, pitch and tar, hemp and flax, and miscellaneous goods such as beer, wax, and copper-kettles. The large imports of timber bear out the early travellers' accounts of the treelessness of Scotland, and timber importers were often exempted from general trade restrictions. The import of Swedish iron should be read alongside the regular shipments of coal which came coastwise to Dundee. Together these indicate the existence of considerable smith-work.

*I have expounded this thesis more fully in Scot. Geog. Mag., Vol. 54, p. 345.

Whilst the town was well situated for the Baltic trade, this by no means monopolised the merchants' attention. Southwards Dundee traded with Flanders, France, Spain, and England. As for certuries before, a large part of this trade consisted of luxury goods, spices, wines, paper and toys, dates, onions, and "racket balls." There were some industrial raw materials, dye-stuffs from Dieppe and Bordeaux, bark (for tanning ?) from England, and, notwithstanding the large home production, salt. It appears that the salt from the pans alongside the Forth was unsuitable for fish curing, and with the development of fisheries in the eastern ports it became necessary to import a better quality.

The export trade still relied largely on the fruits of the land, the rivers, and the sea, for Dundee had consolidated its position as a collecting and distributing centre both for the neighbouring lowlands and for the Highlands. It shared with Perth the trade in Highland horses, coasting vessels brought down fish and butter from the Orkneys, and herring from the Hebrides. The manufactured goods exported consisted mainly of plaiding and other textiles. The Wedderburne "Compt Buik" throws much light on this side of Dundee's activities as well as on the commercial practices of the time. Occasionally a merchant sailed, but as a rule the skipper took charge as agent for the owners of the cargo. So in 1593 Wedderburne handed to Alexander Renkyne, skipper, 18 score and 10 ells of bleached linen, which he was to sell "quhair he hapnit to mak mercat." With the proceeds he was to buy gros-grained silk, if it could be got for 10 franks or less, and send it to Dundee by the first home-bound vessel. If such a purchase were impossible the money had to be lent on the best terms available. Then the shrewdness of the Scottish merchant becomes apparent. Peter Imrie, Wedderburne's relative, sailed on the same boat and received this injunction, "I pray you gif your counsell and attendance on Alexander Renkyn to sell my . . . lyning."

Scotland's trade in the early 17th century was still passing along channels cut three centuries earlier. According to Fynes Moryson the Scots had refrained from long voyages, not through lack of energy, but rather for want of capital. So far they had not joined in the scramble for colonial trade. When they did the whole economic centre of gravity of Scotland shifted westward. Dundee could neither resist this change nor yet participate in the profits immediately resulting from it. Her era of prosperity ended about the middle of the 17th century. In the Civil War, Monk captured the town—tradition has it that the garrison were "well drenched" in "large morning draughts of ale," slaughtered one-sixth of the inhabitants and took great plunder. "They gatt a very rich bootie ther," says John Lamont, "not onlie of the inhabitants, bot also of severall strangers. They gatte many ships in the harbery, nire by 200 veshells, great and small." Among this plunder was a store of cloth belonging to the factory at Newmills (Haddington). Soon after the harbour was destroyed by storm, and though a collection for its repair was taken in churches throughout the country, it remained ruinous and "choaked up with sand" until Defoe's time. The records of the Gild Merchant are consistently doleful: "the tounes low conditione," "ye decaying state of ye Burgh," a great many references to the town's creditors and ruinous houses, and from time to time the purchase of oatmeal from the north of Scotland for distribution among the destitute. To these local misfortunes must be added those acts of government which

affected the whole of Scotland. The temporary union with England (1654-60), the wars with Holland, and Colbert's protection in France all hampered Scotland's overseas trade. The monotonous reiteration of the Scottish merchants' grievances over the loss of ancient trading privileges indicates that the old commercial intimacy between Scotland and France was being destroyed even before the Union of 1707 imposed on Scotland the full weight of England's anti-Gallic prejudices. The Union, it is generally agreed, ruined the woollen industry, though by way of recompense it opened a " prodigious vent " for linens. Dundee had a small part in the Darien Scheme. The Gild Merchant, for example, invested £2,000 of its public stock, but the losses involved in this venture were a minor factor in the long depression. Dundee's prosperity came to an end forty years before the Darien Scheme, and it was not until the middle years of the 18th century that the town was able to reap any of the benefits of union with England. Between 1645 and 1695 Dundee fell from second to fourth among the leading Scottish towns. From 1650 to 1750 its population probably increased by about 50 per cent., reaching a total of 12,000 at the latter date, but in the next half-century alone it doubled. Its economic life continued sluggishly along lines already laid down. Raw materials from the hinterland were still prominent in the export trade, paving and mill-stones from the Carmyllie quarries to London and Holland, wheat and barley from Strathmore and the Carse of Gowrie to Dunkirk, Amsterdam, and London. Dofoe found that Dundonians had " a very large Correspondence with England," especially in corn and linen. He noted the extensive grain-granaries by the Tay, and found that rents on the Carse were paid in kind and the landlords disposed of their stocks through Dundee grain merchants. In the staple textile industry there was a tendency to abandon the woollen branch, plaiding and bonnets, in favour of linen. Thread-making, according to Defoe, was a " famous " Dundee industry, but apart from this Dundee already concentrated mainly on the coarser end of the linen industry. The home-grown flax was roughly treated in the preliminary stages by local growers and thus unfit for the finer yarns. The imported flax, from Riga and Petersburg, was regarded by contemporaries as much poorer in quality than that grown in Britain. And as early as 1735 linen from Dundee and district was being sent to London for shipment to the American colonies, the great market for coarse linens.

When, by the second half of the 18th century, prosperity was again lapping against the walls of Dundee, the manufacture of coarse linens was the staple occupation. By the 1770's David Loch could speak of Dundee as large, prosperous, and " greatly increased within these twenty years, and still continues to be enlarged." Of the factors responsible for this vitality some were peculiar to Dundee, others common to the whole of Scotland. The Board of Trustees, established in 1727, lost no time in encouraging the making of coarse linen suitable for the Plantation market, where, owing to the " drawback " system, German Osnaburghs and Silesias occupied a favoured position. By the 1740's they could report that the making of Osnaburghs had commenced in Dundee and Arbroath. Already by 1741 the quantity of linen stamped had risen to nearly five million yards, more than double the 1728 figure, and under pressure from manufacturers parliament introduced a policy of subsidizing exports which was maintained with slight breaks down to 1832. The bounty rates as fixed in 1745 were :—

Linen worth under 5d. per yard.		bounty	½d. per yard.
,, ,,	over 5d. and under 6d.	,,	1d. ,,
,, ,,	,, 6d. and ,, 1/6d.	,,	1½d. ,,

The average price of all linen stamped in Scotland in 1727-8 was 11d., in 1738 9½d., and in 1748 just over 9½d. The average prices in these years for Forfarshire linen were just under 6d., 5¾d., and nearly 6¼d. In other words, the makers of course linen received as great, or almost as great, a subsidy as those, for example, in Lanark, who made linen of considerably higher value. The bounty system was thus weighted in favour of the coarser end of the trade.

The Jacobite rising of 1745 produced two salutory effects for Dundee. The first was the movement, initiated by various notable persons, for the establishment of a company to promote the linen industry, especially the export of linens to America and Africa. By 1766, according to Postlethwayt, this British Linen Company had considerable stocks of Osnaburghs in London ready for shipment to America and the West Indies. The second beneficial result of the '45 was the abolition of hereditary jurisdictions. The effect was perhaps psychological rather than directly economic, but as Warden says, with the expropriation of the rights of the Duke of Douglas, " the town began to emerge out of the gloom in which it had so long been shrouded."

So when the second half of the 18th century opened Dundee's fortunes were rising. Her place in the linen trade was clearly established, though the industry was widely dispersed through the neighbouring districts. Both spinning and weaving were still in the domestic stage, and the entrepreneur, the capitalist merchant, was an essential link in the organisation. The efforts of official and semi-official enterprise, and the dislocation of the competitive industry on the Continent by the Seven Years' War, all worked to her advantage. But whilst linen had replaced woollens as the main article of manufacture and export, it by no means monopolised the energies of the town. The commercial life and shipping never really recovered from the destruction of shipping and property in 1651 and suffered from the westward shift of Scotland's commercial life, but at the end of our period, in 1759, the author of the " Universal Geographical Dictionary " could write " Dundee is one of the best ports for trade in all Scotland, particularly for foreign, yet it has considerable inland business also, especially for corn and linen cloth." For the economic history of Dundee reveals no abrupt changes, but a very faithful adherence to tradition.

2.—THE DEVELOPMENT OF THE LINEN AND JUTE INDUSTRIES FROM THE DOMESTIC SYSTEM TO THE GREAT WAR

BY

DENNIS CHAPMAN, B.Sc.(Econ.).

Introduction.

This paper, which covers the period of the industrial revolution for the coarse linen industry of Dundee and the establishment and the great expansion of the jute industry, will seek to explain both the reasons for the establishment of the jute industry in Dundee and the emergence of Dundee as a single industry town. It will be necessary to concentrate attention mainly upon the textile industry, but some mention will be made of the whale fishing and the shipbuilding industries. It is obvious that, in an article of this length, it will not be possible to treat the more human aspects of industrial development that are comprised under the heading of " Life and Labour." It is, however, hoped to break some new ground by drawing attention to the work of the Brown Family, who undoubtedly played a decisive part in the transformation of the industry in the period of the industrial revolution.

Part I.

The Industrial Revolution and the Establishment of Jute.

The situation of Dundee as the port for Angus, whose chief industry depended on an imported raw material, Baltic flax, and whose production was almost entirely for export, led naturally to its development as a merchant centre. The founding of the Dundee Banking Company in 1765 by George Dempster was important in that it made available the capital necessary for the expansion which came first of all in the industry on a domestic and later on a factory basis. There was, however, little development of Dundee as a manufacturing centre owing to the almost complete absence of water power; indeed, water was so scarce as to make it difficult to run steam engines. Wm. Brown, writing in 1816, records that an important disadvantage of Dundee was that water was " scanty " and of a " quality hurtful to boilers." There were attempts to establish steam-driven spinning mills in Dundee after 1793, but the first successful mill appears to have been started in 1798 by George Wilkie with a 20 horse power Watt engine. By 1800 there were 5 mills with some 60 h.p. between them.

The Brown Family Pioneers of Mill Spinning.

Until 1806 no progress was made; in this year, however, James Brown built the Bell Mill, which was to be the model of all subsequent ventures for the next 20 years. It was of fireproof construction and had the latest machinery from Leeds. It appears that James Brown had considered building the mill

for cotton, and in his deliberations he had sent his son William Brown to study the linen industry in England, where the latter visited Porthouse, the co-inventor with Kendrick of the flax spinning frame.

Just as his father had effected considerable improvements in mill construction, so William Brown made improvements in technique which were to be the model for the first great advance that the industry made between 1825 and 1826. In 1809 he took over George Wilkie's mill, which was in a ruinous condition, and reorganised it, by 1811 it was working, and he then commenced a long series of experiments in the many branches of mill spinning. He kept manuscript records of these experiments, which covered such topics as labour management, on which his views were remarkably modern, mill sanitation, fire drill, steam engines, spinning frames and, in particular, the carding of tow. Some measure of his success may be made from the fact that between 1813 and 1816 he doubled his putput and at the same time reduced its cost from 10d. per spindle to 6d. per spindle. His attention was directed mainly to developing the spinning of tow, the waste produced when flax was dressed, and so well did he succeed that by 1819 he could write that "Tow yarn of 6/6 per spindle now almost superseded flax yarn of the same weight, and cloth made from it in many cases passed without being known."*

This perfection of tow spinning was important, because it was the beginning of the tendency towards the utilisation of cheaper fibres and because the processes of preparation, particularly carding, were adapted at a later date for jute.

The Introduction of Jute.

According to the traditional theory, the presence of ample supplies of cheap whale oil necessary to soften the fibre before spinning was the deciding factor in the establishment of the jute industry in Dundee. It appears, however, that the Linen centres of Aberdeen, Inverness, Kirkcaldy, Belfast, and Leeds—through the port of Hull—all had easy access to whale oil, which was at that time the universal illuminant. It is therefore necessary to seek some further explanation. This is to be found in the differences between the various kinds of linen produced in the different centres : Dundee alone had a large trade in the particularly coarse baggings made of hemp and coarse tow which were used for the packing of cotton wool, and it was in the production of these that jute was first employed.

The development of tow spinning was the first stage in the utilisation of cheaper fibres, it was followed in 1816 by the introduction of Sunn hemp —again in the coarest end of the trade.

From 1826 to 1835 was a period during which, in years of bad trade, there were many experiments with jute, but the fibre was not really established until the slump period after 1836. This was the result of the coincidence of many factors. On the technical side there was the invention of batching—the softening of the fibre with a mixture of oil and water ; this appears to have been a modification of hemp technique. On the economic side there appear to have been the following factors :—

*I should like to acknowledge the assistance of Mr J. Norman Methven, who very kindly gave me access to the manuscripts on which this section is based.

1. The origin and nature of the slump.
2. Indian competition.
3. The establishment of a market for jute products.
4. Direct trade with India.
5. The fear of the interruption of supplies of flax and hemp.

1. *The origin and nature of the slump.*—The immediately precipitating factor appears to have been a vast over-production of hemp bagging for cotton wool. In 1834 there had been a boom in this particular commodity, and in 1835 there had been a large warehouse fire in New York which had destroyed much of the American stock of bagging. Hemp prices were low, and there appeared to be possibilities of considerable profit. The result was considerable over-production, and the price of bagging fell from 7½d. a yard in 1835 to 5½d. a yard in 1837, whilst at the same time the price of hemp rose from about £25 per ton to £41. These conditions made it necessary for cheaper raw materials to be used if the trade was to continue.

2. *Indian Competition.*—This was an entirely new factor which appeared in this same market. The following report from the Dundee *Advertiser* of May 17, 1839, illustrates the situation: "It appears that the customs house at Philadelphia are admitting a species of gunny bagging from the East Indies, duty free, which is likely to totally supersede the cotton bagging (hemp bagging for cotton) from Britain, on which there is a duty of nearly 2d. per yard.

3. *The establishment of a market for Jute products.*—A Mr Rowan, who in 1833 had experimented with jute, had for long supplied the Dutch Government with tow yarn for coffee bags. In 1838 he persuaded them to use jute yarns.

4. *Direct Trade with India.*—In May 1839, Dundee obtained the privilege of direct trade with India, which brought about a saving of 17 shillings a ton on jute.

5. *The fear of the interruption of Flax supplies.*—This fear had been present in the minds of the Dundee merchants since the period of the Napoleonic Wars, and when in 1838 it was feared that there might be a war with Russia arising out of the tension of the first Afghan War, the Dundee press devoted much attention to possible new sources of raw material.

These factors brought about the considerable use of jute, as a substitute for hemp and tow, and as an adulterant of tow in the coarsest fabrics. It was not until 1848, however, again in a period of depression, that James Aytown of Kirkcaldy, a spinner who had done much to perfect tow spinning, conducted experiments which enabled Jute yarns to be woven without sizing. This enabled the use of the fibre to be greatly extended.

TABLE I.

TOTAL IMPORTS OF FIBRE INTO DUNDEE.

1796 to 1850.

Year.	Tons.	Year.	Tons.
1796	3,336	1835	27,130
1815	2,187	1840	27,980
1820	4,958	1845	41,944
1825	13,902	1850	55,718
1830	20,496		

We may now sum up the development of the industry to 1850, which made possible the great expansion of the Crimean and American Civil War periods. There appears to have been little quantitative expansion in the industry until after 1816, when for the first time total fibre imports were greater than those of 1796, although the considerable technical advances had been made.

There was a very considerable expansion between 1816 and 1826, followed by a period of steady progress until the violent increase of the boom year of 1836. In the slump which followed, jute was successfully introduced, and it soon almost completely replaced hemp, and was widely used with tow in many of the coarser fabrics.

Part II.

The Economic Development of the Jute Industry, 1850 to 1918.

The successful establishment of jute manufacture has already been described; this section will trace the further development of the industry with special reference to the present situation and to the emergence of Dundee as a single industry town.

1. The Perfection of Technique and Organisation.

There remains one important improvement in technique which came before the expansion of the Crimean War period: this was Worral's wood clothed card. The new jute industry had taken over the carding machine, which had been used for tow preparation. This had an arrangement of steel staples drawn through leather as a means of combing or carding the fibre. The coarse and dirty jute fibre quickly destroyed this "card clothing" and necessitated repairs which were both slow and expensive. Worral's improvement consisted in replacing the leather with hardwood staves into which tempered steel pins were inserted. The new card, which was more efficient, more durable, and easily repaired, came into general use shortly after its invention in 1853. This was followed in 1857 by a great advance in the organisation of plant in the Bow Bridge Works, which set the pattern for the great expansion which followed the American Civil War in the same way as James Brown had done some 50 years earlier.

2. The Influence of War Demand.

Warden has summarised the effects of the Crimean War as follows:—"During the Crimean War an immense demand sprang up for coarse linens, and the manufactures of Dundee were largely consumed by both belligerents during the siege of Sebastopol. The profits thus realised stimulated enterprise, and led to the erection of extensive new works for spinning and weaving by power and great additions to previous ones."* Dundee had imported record quantities of flax in preparation for the war, which threatened to cut off supplies, and during the war, when flax imports declined, jute imports increased and became as important as those of flax.

Following the depression of 1857 Dundee trade developed slowly until the second year of the American Civil War. The shortage of cotton increased

*Warden, A. J. *Linen Trade* (London, 1864), p. 618.

†Boase, C. W. 1867. *A Century of Banking in Dundee.* Edinburgh, Grant & Son. p. 505.

the demand for linens, whilst at the same time both armies were using very large quantities of the coarse products of Dundee. Much of the profit of this trade was devoted to the expansion of the industry, many firms building calenders, whilst two firms, Messrs Cox and Messrs Grimond, bought clipper ships to bring jute direct from Calcutta. The extent of the expansion can be measured by the increase in the total imports of fibre—from 75,000 in 1863 to 91,000 tons in 1864 and 116,500 in 1865. Warden estimated the value of the annual product of the industry as 5 million pounds in 1864 and 8 million pounds in 1867, which may be compared with the estimate of 3½ million pounds made by the manager of the Dundee Banking Company in 1857.†

3. The Great Jute Expansion.

After the end of the American Civil War there was a short period of bad trade, but the next few years were to be the most profitable in the history of Dundee.

The Calcutta industry had been established, but its growth, so far, had been largely at the expense of native production. The continental industry was as yet insignificant. Dundee thus had an almost complete monopoly.

At the same time there was an enormous growth in demand resulting from the opening up of the American West by railways ; the increase of American agriculture and the Franco-Prussian War. At this time about one-half of Dundee's production was going to America. By 1871 the import of jute into Dundee passed 100,000 tons, and by 1873 the peak of the boom was reached with an import of over 140,000 tons.

The extension of plant was of an entirely different order, by 1874 the number of spindles being almost doubled and the number of looms and operatives more than doubled in comparison with 1870. (These returns relate to Scotland, but in practice the jute industry was almost confined to Dundee.)

Table II.

Growth of the Scottish Jute Industry.

Year.	Spindles.	Looms.	Persons Employed.
1870	94,520	3,744	14,911
1874	185,419	8,325	37,920
1878	183,056	10,009	30,401
1885	225,399	10,856	36,269
1890*	268,165	14,107	43,366
1905*	263,938	13,704	40,861†

*Returns for U.K. †Return for 1904.

4. Competition and Tariffs.

The development of the Calcutta industry had the effect of limiting the growth of the Dundee industry, but did not endanger it until much later, because for long there was a large demand for types of fabrics which could not be produced by the less skilled native labour. The rate of development of Calcutta was very rapid, especially between 1865 and 1875, when the number of spindles increased from 12,000 to 59,500. This increase continued until 1894, after which there were enormous and spectacular increases.

Competition from Calcutta rapidly ousted Dundee from the coarse market, and by 1886 Dundee had lost her markets of Australia, the Cape, and the San Francisco market for grain bags. The period after 1880 was marked by the imposition of tariffs which very considerably reduced Dundee's trade with the Continent. By 1886 Austria, France, Germany, Italy, Russia, Spain, and U.S.A. had imposed heavy tariffs on various categories of jute imports.

5. Investment out of Jute.

The effect of this new competition, together with the partial exclusion of Dundee from many of her markets by tariffs, explains why the equipment of the industry did not expand greatly after 1874 (Table II.), although it will be seen from the figures of Jute Imports (Table III.) that the consumption of Jute doubled in the later years of the century. A consideration of a number of other factors will go some way towards explaining why no other considerable industry was established in the area.

Table III.

Imports into Dundee, Tons.

Year.	Jute.	Flax.	Tow.
1850	14,080	31,572	8,962
1855	25,894	23,018	5,112
1860	36,965	23,801	4,455
1865	71,702	36,147	6,624
1871	102,844	39,361	11,544
1875	113,930	22,572	6,500
1880	103,423	29,979	8,387
1885	175,688	28,451	4,800
1890	238,884	24,230	4,888
1895	277,315	24,551	5,124

It is likely that the expansion of the industry in the period before 1874 was greater than was profitable, so that it was to be expected that Dundee's investments after this date would be directed to other channels. Important factors in the direction of this investment were the geographical isolation of the area from internal markets, the lack of coal and iron in the district, and the relatively unproductive nature of the hinterland, much of which was sporting estate. In connection with the factor of isolation, it must be remembered that the first Tay Bridge was not opened until 1878, and was destroyed in the same year and not reopened until 1887. The Forth Bridge, which was also important to Dundee, was not opened until 1890.

It is, therefore, not surprising that Dundee's investment was not to any great extent devoted to new projects in the locality. On the other hand, the intimate relations with the U.S.A. which had developed from the very important trade which the city had in Jute and Linens with that country had much to do with the formation after 1879 of the prudent Scottish American Investment Trusts and the more speculative ventures into land and cattle companies and railways. Dundee also had investments in Australia, Canada, Ceylon, New Zealand, and Hawaii. To this period belongs the formation of the two new Dundee Calcutta Jute Companies—the Victoria and the Titaghur—founded in 1884.

The Pre-War Jute Industry and the Decline of Linen, Shipbuilding, and Whaling.

As has been seen from Table II., there was no great increase in the size of the industry after 1874; it was, however, fairly prosperous, and, as will be seen from the imports of jute, Table IV., had reached a position of relative stability in the pre-war years. It seems likely that to some extent Dundee's position was dependent on the various measures of restriction of output which were employed by Calcutta in one form or another during most of the period from 1886 to 1912.

Table IV.

Jute Imports Retained for Consumption in U.K.

	Tons.
1900	172,981
1901	199,366
1902	291,853
1903	159,507
1904	203,177
1905	226,675
1906	230,936
1907	225,413
1908	249,175
1909	199,429
1910	201,490
1911	190,302
1912	244,588
1913	220,995
1914	158,035

The position of linen was not so satisfactory. By 1886 the import of flax was only about a half of what it had been in the boom years of the American Civil War, and there were only three firms left in the town which specialised in flax, and these were very largely dependent on government contracts. This decline continued except for a peak in 1895, until a low level of only 13,390 tons was reached in 1910. This may be accounted for partly by the reduction in the tonnage of sailing ships, which declined from nearly 4,000,000 tons in 1880 to just under 800,000 tons in 1914.

Competition from mineral oil, together with increasing difficulties in the Arctic fishing, caused the almost complete extinction of the Dundee Whaling fleet by 1914.

The position in shipbuilding was similar: the latter years of the 19th century saw four firms close down, leaving four firms working in 1900. In 1908 one of the largest of these closed down, and in 1912 yet another, so that whereas the gross tonnage launched in Dundee between 1905 and 1908 averaged 22,000 tons, the output in 1909 was only 8,000 tons and in 1910 6,000 tons.

Summary and Conclusion. Dundee as a Single Industry Town.

The decline in Dundee's subsidiary industries had made the city more dependent on the jute industry in the immediate pre-war period than it had ever been before. At the same time it seems that the prosperity of Dundee

was to a considerable degree dependent upon the policy of restriction in Calcutta. It appears unlikely that Dundee was better equipped than its rival; indeed one observer writing in 1913 stated that in size, lay-out, and equipment the Scottish industry was behind that of Calcutta.*

The outbreak of the Great War, therefore, came at a time when the jute industry was in very weak competitive position. During the war Dundee had a period of prosperity, hampered occasionally by shortage of raw material. This had the effect of giving a very considerable new lease of life to plant, much of which was already obsolete. The Calcutta industry increased in size during the war and gained positions in markets that Dundee was forced to neglect.

The position of the city and its main industry at the end of the war was as follows. Owing to the concentration on war-time needs there had been no replacement of the important subsidiary industries of whale fishing, linen, and shipbuilding. The Jute industry which had been in a weak position in 1914 found that it had to face even greater competition from India than before with plant that had not been replaced during the war period.

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*Clark, W. A. G. (1913). *Linen, Jute, and Hemp Industries in the United Kingdom.* Special Agents Series, No. 74. Washington Government Printing Office. p. 106.

3.—THE INVESTMENT TRUSTS IN DUNDEE

BY

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Dundee is sometimes referred to as the home of the investment trust movement. The success of the Scottish American Investment Trust, established in Dundee in 1873, and the prominent part taken by its founder, Robert Fleming, in the whole movement, were of great importance in the development of investment trust finance.

Robert Fleming visited the United States in 1870 on behalf of his principal, Edward Baxter, who had large interests in American securities. He returned to Dundee greatly impressed with the importance of that country as a field for the investment of British capital. At this time the jute industry was very prosperous and Dundee had capital available for foreign investment. Fleming was able to impress financial men in Dundee with the advantages of the United States as a field for investment, and in February 1873 the Scottish American Investment Trust was formed. The First Issue of £300,000 was made in this year. The Scottish American Investment Trust (First Issue) was to terminate at the end of ten years, when the investments were to be realised and the proceeds divided *pro rata* among the holders of unredeemed certificates. The issue had been made in the form of bearer certificates of £100 each. The capital was invested mainly in United States railroad

mortgage bonds, which were carefully selected. The annual income from the investments, after payment of management expenses, was fully 7 per cent., so that a large surplus was left after payment of the interest at the fixed rate of 6 per cent. on the trust certificates. It is interesting to note that John Guild, the chairman, enunciated one of the fundamental principles of investment trust finance at the first general meeting of the Trust: "Perhaps the chief advantage of the Trust is the distribution of risk which it so simply accomplishes. A holder of a single £100 certificate has an interest in thirty different carefully-selected bonds; not more than £7 of this capital is placed in one security in any case, and on an average not much more than £3 of the £100 certificate is placed in any one investment."

The first year of the Trust's operations was a difficult one. When the investment of the £300,000 capital was almost completed, a severe panic developed in the United States. Robert Fleming, who was secretary to the Trust, confessed that the 1873 panic invaded his dreams. The First Issue, however, weathered the panic, and did well during the difficult slump years which lasted until 1879.

Robert Fleming and his associates early began to expand their operations. In the Trust's first year a Second Issue of trust certificates, amounting to £400,000, was made. This issue was subscribed just before the panic, and was invested after the panic when the prices of bonds were low. The funds of the Second Issue were also invested mainly in mortgage bonds of United States railroads, and the average amount of each investment was considerably less than one-fiftieth of the capital.

A Third Issue, amounting to £400,000, was made in 1875. This issue brought the total amount of capital controlled by the Scottish American Investment Trust up to the large amount of £1,100,000. The three issues of certificates made by the Trust proved to be very remunerative investments in the difficult seventies. Six per cent. interest was paid annually on the certificates of all three issues and large reserve funds were accumulated. In 1879, for legal reasons, the Scottish American Investment Trust, with its three issues of certificates, was on March the 24th registered as three distinct companies under the Joint Stock Companies Acts. These companies were the First, Second, and Third Scottish American Trust Companies. The trustees were able to point out at this time that "The Scottish American Investment Trusts were never in so prosperous a condition as they are at the present time. At present market values of the Assets of the Trusts the New Companies will start with a Reserve Fund in the aggregate of over a Quarter of a Million Pounds sterling, and with a net Revenue of between Eight and Nine per cent. per annum."

For thirty years, until 1910, the capital of the three Scottish American Trust Companies consisted entirely of ordinary stock. No preference stock or debentures were issued, in contrast to the Dundee land trust companies. Good, steady dividends were paid by all three companies, although the period included both good and bad years. During these thirty years the First Company paid regular dividends of from 8 to 8⅜ per cent., slightly over 8¼ per cent. on the average. The Second Company paid regular dividends of from 8 to 8½ per cent., and the Third Company of from 7½ to 7¾ per cent. The somewhat lower dividend of the Third Company was due to the fact that its capital had originally been invested at a less favourable time. The

prices of United States railroad bonds were higher in 1875 than in 1873. The Companies pursued a conservative policy of building up large reserve funds, and they were able to pay steady dividends by maintaining a good margin between earnings and dividends in good years, which could be narrowed during a depression.

The great success of the Scottish American Trust Companies stimulated the directors to form a sister company in 1896, the Northern American Trust Company, Ltd. The investment powers of the new Company were much wider than those of the old Companies, being universal, general powers, but the prospectus stated that it was intended to invest the great bulk of the share and debenture capital in " bonds of railroads and other corporations and undertakings in the United States, including States or Municipalities, but chiefly in the mortgage bonds of railroads there." The Northern American Trust started with a paid-up capital of £300,000. The more modern capital structure was adopted for this Company ; the capital was arranged in the proportion of 60 per cent. in 4 per cent. preferred stock to 40 per cent. in ordinary stock, and a limit of 100 per cent. of the total capital was imposed on the issue of debenture stock. During the Company's first year £300,000 of 3½ per cent. debenture stock was issued, and its borrowing power was thus temporarily exhausted.

A policy of capital expansion was pursued on behalf of the Northern American Trust in its early years. By 1908 its total capital had been raised to £1,000,000, and its debenture debt to the same amount. The debenture debt was now in two forms ; debenture stock of £750,000 and terminable debentures of £250,000. The figures for capital and debenture debt remained unchanged until 1924, apart from small changes in the amount of terminable debentures. The expansion of the Northern American Trust was stimulated by its great success. From 1897 to 1914 the dividend was raised by one per cent. every two years from 5 per cent. to 13 per cent. A large reserve fund was also accumulated.

The excellent results of the Northern American Trust caused the directors to make important changes in 1910 in the conduct of the sister Companies, the three Scottish American Trust Companies. The powers of investment were extended and provision was made for the issue of debenture stock. Up to 1910 investments had been mainly restricted to bonds of railroads in the United States, but now they were made in a wider field. The wider powers of investment were, however, used only moderately, and in 1912 the investments still remained to a preponderant extent in the United States. The new borrowing powers were fully used, and by 1911 the three Companies had all issued debenture stocks. Dividends now increased, and by 1914 the First, Second, and Third Companies were paying dividends of 9⅜, 9½, and 8¾ per cent. respectively.

In 1913 the Camperdown Trust Company, Ltd., was formed, having as its London correspondent Robert Fleming & Co. This Company started with a capital of £300,000.

The land mortgage companies, which were developed about the same time as the Fleming Companies, formed a second group of trust companies in Dundee. The Alliance Trust Company, Ltd., which is now the largest investment trust in Europe, was formed in 1888, but its history can be traced back to 1873, the same year as the foundation of the Scottish American

Investment Trust. The Alliance Trust had its origin in the Oregon and Washington Trust Investment Company, Ltd., which was promoted by William Reid to invest in land mortgages. In 1874 William Mackenzie, who created the Alliance Trust by his policy of amalgamations, was appointed secretary to the Oregon Trust. The Trust invested in mortgage loans in the State of Oregon and Territory of Washington, and derived great advantage from the high rates of interest at this time. The mortgage loan rate was 12 per cent. in 1877 and 10 per cent. in 1878. From the start the practice of raising part of the funds for investment in mortgage loans by borrowing on debentures was followed. By 1878 the Company's capital amounted to £50,000 and its borrowed money to £132,046. The Trust was very successful and paid good dividends.

The directors of the Oregon Trust promoted in 1876 the Dundee Mortgage and Trust Investment Company, Ltd. William Mackenzie was also secretary of this Company. The chief objects of the new company, like those of the old, were to borrow money at a comparatively low rate of interest and to lend its paid-up capital and borrowed money on mortgages abroad. Unlike the Oregon Trust, however, the Dundee Mortgage Company was permitted to invest anywhere in the United States and the British Empire. Further, the securities of the new Company were not to be confined to mortgages over lands and other real property, although they were to form the chief and favoured class. In 1879 the Company had a capital of £70,000 and borrowed money amounting to £285,341. Mortgages over real estate in the United States and Canada amounted to £318,187. The Dundee Mortgage Company was able to pay very satisfactory dividends from the beginning.

In 1879 William Mackenzie began his policy of amalgamations by combining the Oregon Trust and the Dundee Mortgage Company. The Dundee Mortgage Company was now an important Company, and in 1880 it had a capital of £118,000 and debentures amounting to £489,881. William Mackenzie proceeded with his policy of amalgamations in 1882, when the Oregon and Washington Mortgage Savings Bank Company, Ltd., was amalgamated with the Dundee Mortgage Company. Mackenzie had become secretary to the Savings Bank in the previous year. It had been promoted by William Reid in 1876 with the main objects of accepting savings deposits in Oregon, borrowing money on debentures in Scotland, and investing its funds in first mortgages over land in Oregon and Washington. The operations of the Savings Bank were always on a small scale, but satisfactory dividends were paid.

The Dundee Mortgage Company felt the great and general depression in the United States and Canada in 1883, when the prices of agricultural products fell to very low levels. The Company was, however, in a strong position, having pursued a conservative reserve fund policy in the past, and the usual dividend of 10 per cent. was maintained up to the amalgamation which created the Alliance Trust.

In 1889 the Dundee Mortgage Company and the Dundee Investment Company were amalgamated to form the Alliance Trust. The Dundee Investment Company had its origin in the Dundee Land Investment Company which was formed in 1878. It was promoted by several gentlemen connected with the Dundee Mortgage Company, and William Mackenzie was its first

secretary. It was essentially a company for speculating in land, the chief object being to buy land and hold it until it could be sold at a high price. By 1881 the Company held real estate in the United States and Canada amounting to £101,577. In 1882 it was reconstituted as the Dundee Investment Company, Ltd., and its policy was completely changed. The speculative policy of purchasing land was given up and the real estate held was liquidated as quickly as possible. The Dundee Investment Company, like the Dundee Mortgage Company, invested mainly in mortgages over real estate.

William Mackenzie's policy of amalgamation culminated in the combination of the Dundee Mortgage Company and the Dundee Investment Company to form the Alliance Trust Company, Ltd. The Alliance Trust was registered on April the 21st, 1888, and took over the business of the two amalgamated companies on November the 1st, 1889. The Alliance Trust was a wealthy company from the start, controlling a total amount of funds in the form of capital, reserves, debentures, and temporary loans of over one and a quarter million pounds. It was definitely a land mortgage company, but even in 1890 the percentage of total funds invested in the mortgage field was only 86·89 owing to the policy of investing reserves in bonds.

The acute agricultural depression which followed the panic of 1893 provided a severe test for the trusts operating in the mortgage field. During these difficult years the Company's revenue suffered, and in 1895 the dividend was reduced from 12½ to 10 per cent. In 1896 the dividend was further reduced to 8 per cent., at which rate it remained until 1905.

There was a large expansion of the capital of the Alliance Trust during the years from 1890 to 1914. By January the 31st, 1915, the Company's capital amounted to £1,500,000, and it had a reserve fund of £800,000. Debentures and interim loans now amounted to £2,205,765. After 1905 there followed a period of rising dividends. In 1906 the dividend was raised to 10 per cent. and by 1915 it had risen to 19 per cent.

Another land mortgage company in Dundee was the Western and Hawaiian Investment Company, Ltd., which was formed in 1883, and which was renamed the Second Alliance Trust Company, Ltd., in 1923. This Company dates back to 1880, when the Hawaiian Investment and Agency Company, Ltd., was formed. The Agency Company was formed to make mortgage loans in the Hawaiian Islands. The Western and Hawaiian Company, which took over the Agency Company's business in 1883, invested mainly in North America. It was entirely a land mortgage company before the War, and even in 1918 81·8 per cent. of its total funds was invested in the mortgage field. By 1915 this Company controlled a total amount of funds amounting to £603,713.

The British Canadian Trust, Ltd., which was registered in 1910, was the last land mortgage company to be formed in Dundee. In 1914 77 per cent. of its total investments was in the form of mortgages over real estate in North America. At this time the Company controlled total funds amounting to £523,922.

The Dundee Trusts did not, of course, expand their operations during the War. Their earnings were, however, fairly well maintained ; no company reduced its dividend, and the Alliance Trust actually increased its dividend

in 1915. Since the War only one new investment trust has been formed, but the capital and debenture debt of some of the old trusts have been greatly expanded. The Dundee and London Investment Trust was formed in 1927, and is independent, like the British Canadian Trust, of the Alliance group and of the group consisting of the three Scottish American Trusts and the Northern American Trust. In 1938 the Dundee and London Trust controlled total funds amounting to £871,245. The Alliance Trust's policy of increasing its capital began in 1921, and total capital amounted to £3,250,000 in 1934, since when there has been no further increase. In 1938 the Company's debenture debt amounted to £5,769,665 and total investments to £11,623,420. The policy of expansion was also applied to the Second Alliance Trust, which had been called the Western and Hawaiian Investment Company until 1923. The management of this Company had been transferred to the office of the Alliance Trust in 1918. The capital and debenture debt of the Second Alliance was increased so that by 1938 its investments amounted to £3,923,003. The three Scottish American Companies split their capitals into ordinary and preference stock in 1928, and at about this time each of the Companies increased its capital by £100,000. In 1938 the total investments of the three Companies amounted to £4,800,005. The Northern American Trust increased its capital in 1924 and in 1925, since when it has remained unaltered. In 1938 its total investments amounted to £4,273,010. The Camperdown Trust showed increases in its capital in 1921 and in 1928. In 1938 its total investments amounted to £1,672,933.

Further important developments in the conduct of Dundee's trusts must be noted. The companies which were interested in the mortgage field have been gradually eliminating their mortgage business and devoting all their funds to general investment. In 1937 the Alliance Trust had only 7·8 per cent. of its funds still in the mortgage field. All the companies have reduced the percentage of their investments located in the United States. This policy was initiated in the pre-War years, and was accentuated during the War when the British Government required American credits. A further change in the investment lists has been a decline in the importance of bonds relative to preference and ordinary shares. There has also been an important change with regard to debenture debt. The English investment trusts have never issued terminable debentures for short periods, while the Scottish trusts have made extensive use of this method of borrowing. Indeed, the Alliance Trust had issued no debenture stock until 1925. A more conservative policy in this respect was now adopted, and by 1936 the Alliance Trust had a larger amount of debenture stock than debentures and short loans.

The financial results achieved by the Dundee trusts were most satisfactory up to about 1932 and dividends were greatly increased. There followed a period of falling dividends due to the effects of world depression. Dividends rose again as a result of economic recovery, but only the Alliance Trust has been able to restore its maximum rate of dividend. The Second Alliance and the British Canadian Trust paid in 1938 dividends only one per cent. lower than their maximum rates. The high level of dividends paid by the Dundee trusts is the result of a high ratio of debenture debt and preference stock to ordinary capital and of the accumulation of large reserve funds in the past.

The accompanying table shows the progress of Dundee's investment trusts :—

Year.	Total Investments (Book Values).
1880	£1,972,736
1890	2,751,380
1900	4,113,540
1914	10,802,567
1920	11,201,646
1930	23,827,650
1938	27,869,450

X.

AN ECONOMIC SURVEY OF PRESENT-DAY DUNDEE

BY

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Industry and Trade of Dundee.

Dundee is a single industry town and the British jute industry is almost wholly located in Dundee. These two facts must form the starting point for any economic or social study of the city. The problems of the jute industry are the problems of Dundee, for not only is that industry the principal employer of labour, but most of the rest of the town gets its living in industries subsidiary to it or by catering for the personal needs of those employed in it.

The population Census of 1931 records 95,175 persons in the city as gainfully occupied, and of these almost 34,000 described themselves as attached to the jute industry. Despite the shrinkage which has taken place during the past eight years, jute remains by far the largest employer of labour, and of almost 72,000 persons in the city registered under the Unemployment Insurance Acts in July 1938, nearly 26,000 were employed in that industry. The intense localisation of the industry is shown by the fact that there are little more than 4,000 persons outside the city employed in it. Apart from the distributive trades, which employ some 10,000 insured persons, all other industrial groups number less than 3,000, and of these general engineering, which is largely textile engineering, and bleaching and dyeing are mainly dependent on the jute industry. Of the rest only linen, printing and publishing, and shipbuilding are catering for an extra-local market.

The coarser types of flax and hemp goods are manufactured in Dundee by a few survivors of the industry, which once provided much of the sailcloth for British shipping and was the parent of the jute industry. There are, indeed, several very old jute firms which were originally founded as linen manufacturers. This industry has benefitted greatly in recent years from the rearmament demands for tenting, sailcloth and other heavy linen for naval and military equipment. There are also one or two firms making fine linens or fabrics of linen mixtures. Of these products Glamis furnishing fabrics enjoy an international reputation for excellence of design.

There are also a few small but prosperous industries in which relatively high transport costs are not a severe handicap. Every member of the Association who purchases post card photographs of Scottish scenery makes the acquaintance of the products of Messrs Valentine, art publishers of Dundee. The Leng Thomson Press publishes morning and evening papers with a wide circulation in East Scotland and also numerous magazines and weeklies with a national circulation. The firm departs from normal practice by employing

a staff of between 70 and 80 artists to produce illustrations instead of purchasing the work of free-lance illustrators. The Press has in the past been a nursery for budding journalists which has provided Fleet Street with some prominent figures.

The product most commonly associated with Dundee by people from south of the Border is marmalade, but the numbers employed are not large. Even when those engaged in the canning of fruit, vegetables, and fish and in cocoa and sugar confectionery are included, the total is merely a normal figure for a town with a population of 180,000. Several canneries have been established in Angus in recent years by English firms who wished to take advantage of the particularly good canning qualities of the local raspberry crop. But as the season lasts only a few weeks, it has been necessary to find other products to fill out the year, and in some cases production has been transferred from the south for this purpose.

Although the Angus shore of the Tay estuary provides ideal sites for shipbuilding yards, other factors have prevented Dundee from retaining the position it once held as a major centre of the industry. The Clyde is close to the steelworks which supplies its plates, while in the neighbourhood of the Tay the spontaneous growth of a steel industry is improbable owing to the distance from supplies of coking coal, the Fife coal being particularly poor for this purpose. Nevertheless, the Tay is still second only to the Clyde in Scotland.

In the nineteenth century the Tay had advantages in certain sections of the market for ships. A large fleet of fully-rigged ships was employed bringing jute from India, and many of these vessels were built in Dundee yards. Some of them are still afloat, and even now the Tay is well represented in the annual grain race from Australia. One of them, the Lawhill, retains her original name, though she no longer flies the Red Ensign. Further, until early this century Dundee was an important whaling and Arctic fishing port, and consequently a local demand existed for the specialised types of vessel needed for these purposes. Such was the reputation of Dundee yards for ships built to withstand ice that the first "Discovery" was built there. Jute is now carried by the passenger and cargo liners plying between India and the Thames; the whaling industry has moved elsewhere, and fishing is quite unimportant. The local market for ships has therefore disappeared.

Nevertheless, the sole remaining yard has been relatively prosperous in recent years. Activity has followed the same general trend as elsewhere, but the slump came later and recovery began earlier than in many other centres. The year 1930 made a record with 41,000 gross tons launched, and although 1938 was a year of closely comparable activity, launches amounted to only 31,000 tons. The slump in output lasted from 1932 to 1935, when for four years launches never reached 5,000 tons a year, but since then launches have exceeded 20,000 tons annually. The present year may break all previous records, as there were more than 27,000 tons under construction at the beginning of the year and an order for three sister ships with a total tonnage of a similar amount has been secured.

The Caledon Yard enjoys a high reputation for passenger-cargo liners of about 9,000 gross tons, and many ships of this type have been built for the Blue Funnel Line of Liverpool, the Glen Line of London, and The Netherlands

Steamship Company of Amsterdam. They have also constructed many tankers for both British and foreign owners. Another speciality has been steamers and motor ships for coastal trade. In its list of launches the names of the same owners recur frequently, and repeat orders for sister ships are common, facts which speak for the quality of ships built on the Tay.

All branches of engineering are carried on in Dundee or its immediate neighbourhood, but with the exception of textile engineering, the scale of production is designed to cater primarily for local demand. The firms engaged include several well-known local firms and a branch of a combine operating in several textile centres. All types of machinery required for the flax, hemp, jute, and linoleum trades are constructed both for the Dundee industries and for Calcutta. The demand for such equipment suffers considerable fluctuations, and plant for a variety of processes is also made. There is also an interesting example of a small but prosperous firm making electrical equipment which was founded as a deliberate attempt to diversify Dundee industry.

The natural advantages of the Tay estuary as a harbour cannot, unfortunately, be fully exploited as there is no densely populated hinterland for the port to serve. The port is very largely dependent on the jute trade, and dues on raw jute alone provide about 40 per cent. of the revenues of the Harbour Trust. Hence the requirements of that industry have been the determining factor in the lay-out of the docks. The considerable length of the deep water wharves on the river front is to be explained by the fact that raw jute imports were formerly highly seasonal. In recent years supplies have been shipped as part-cargoes and arrivals have been spread over eight months of the year. The trade in raw jute amounts to a million bales a year, and some half-million tons of shipping brings it in. The trade of the port is dominantly inward, for in addition to raw jute there are imports of sacks and gunnies, timber amounting to some 60,000 loads a year, esparto grass for the local paper mills, raw sugar to occupy the Cupar refinery when the beet season is over, flour, and phosphates. Some hessian is exported from Dundee, but more is despatched from the Clyde or from English ports. The fact that the one important exporting industry of the town has its chief markets on the other side of the Atlantic makes it inevitable that goods will be despatched via the ports handling the Atlantic traffic. There is a direct service to the United States but sailings are not frequent. The liners which bring the raw jute pick up cargoes elsewhere for the outward passage to India. Much of the outgoing traffic is coastal trade, and potatoes for England are an important item.

The Jute Industry.

Jute is one of the cheapest textile raw materials, but it is, compared with cotton or flax, coarse, relatively brittle, of unattractive appearance, and difficult to dye in fast bright colours, so that the industry has tended to develop by substituting jute for other materials in uses where cheapness is the primary consideration. Some 70 per cent. of the world's output of jute cloth is used for packing purposes, either made up into sacks or as wrapping material. Next comes the use of the finest qualities of "hessian" as the base of linoleum and oilcloth, and the third major use is in jute carpets and matting. Apart from these there are less important uses too numerous to mention, but important in their aggregate consumption. The variety of

applications of jute can be seen from such examples as the use in brattice cloths for regulating mine ventilation, in upholstering furniture, in making the so-called buckram foundations of cheaper tailored garments, and as a wall covering. The yarn is used for purposes as diverse as the backing of carpets and rugs made of other materials, for making string, and as insulation in electric cables.

These are but a few of the many jute products made in Dundee, indeed there can be few which the city does not produce, but ever since the phase of rapid expansion in the local industry came to an end in the middle 1870's, the tendency has been for the cheaper fabrics and sacks to form a diminishing part of output, while more attention is paid to the production of the finer qualities of hessian and to certain specialised lines where the total demand is insufficient to attract the large-scale producers of Calcutta.

In 1914 the jute industry of Dundee had been nearly stationary for some forty years, while rival industries on the Continent, and above all in Calcutta, expanded. Since the war the output of the Dundee industry has declined slightly and that of its principal rivals has increased still further. The decline in output has not, however, even approached the dimensions of that suffered by the cotton industry. In pre-war days net imports of raw jute averaged 220,000 tons a year, compared with 197,000 tons in 1938, when consumption returned to approximately the pre-slump level. A similar decline in the production of yarn is shown by the census of production figures, which give an output of 116,500 tons for 1935, compared with 102,500 tons for 1930 and 132,000 for 1912. In the early months of this year output may have reached the pre-war level, but statistics are not available. The decline in the competitive position of Dundee is, however, greater than the figures show, for through Government intervention a certain amount of business comes to Dundee irrespective of price. Examples of this are orders for sandbags which could be placed more cheaply in India but are given to Dundee firms so far as local productive capacity permits; Danish bacon must be imported in Dundee-made cloth, and subsidised British beet sugar must be packed in Dundee sacks. The effects of such arrangements can be seen from the fact that one standard grade of cloth can be delivered in Dundee from India at a price which covers only the spinning cost of a Dundee manufacturer. If it were competing in an entirely open market the rate of output at the present time would not compare so favourably with pre-war figures.

In pre-war days the industry exported about 40 per cent. of its output, and the proportion actually rose after the war to 52 per cent. in 1924, falling again to 45 per cent. in 1930. No inclusive figure can be given for a more recent year, but according to the 1935 Census of Production, exports of piece goods amounted to 31 per cent. and exports of carpets and rugs to 13 per cent. of respective outputs, and since piece goods are by far the more important, the average would be much nearer the former figure than the latter. In addition, some 5 per cent. of yarn is exported, and a small proportion of the piece goods output is exported as sacks. About 80 per cent. of the export trade is with foreign countries, half of it with the United States alone, so that the prosperity of Dundee is closely linked with that of America and also to changes in the height of barriers to international trade. As regards the home market, imports of yarn are negligible and those of carpets and rugs relatively unimportant. In the case of piece goods it is unfortunate that the trade

statistics do not distinguish between the different kinds so that the differences between the types of cloth imported and those which are exported do not appear. It is probably not far from the truth to say that the qualities exported are quite different from those imported. Until recent years retained imports of piece goods represented some 20 per cent. of home consumption, but since 1935 imports, which come mainly from British India, have increased each year, the figure for 1938 being nearly treble that of 1935. At the same time home production was greater in 1938 than in 1935 and exports were reduced by a third, so that Dundee's share of the home market was not reduced to the extent the import figures suggest. The increase in piece goods is due to circumstances in the Calcutta industry, of which some account may now be given.

Calcutta and Dundee may be regarded as sharing the world export market for jute goods between them, Calcutta being by far the bigger of the two. The members of the Indian Jute Mills Association, who represent 96 per cent. of productive capacity in India, consume five or six times as much jute as Dundee, but owing to restrictions on output in Calcutta, this comparison underestimates the relative size of the industry there. The general tendency is for Indian mills to cater for the bulk demands for the coarser types of fabric and to leave to Dundee the finer qualities and certain widths and weights of coarser cloths the demand for which is insufficient to make its production attractive to Calcutta. The Calcutta mills are highly integrated, spinning, weaving, and finishing being carried out in the same building; labour is cheap and transport costs are lower. Indian wage rates are much lower than those in Dundee, and even allowing for a lower efficiency of labour and the cost of white supervisory labour, which has no equivalent in Dundee, where "blackcoated" jobs are few, wage costs are lower in Calcutta. Dundee, on the other hand, has the advantage of a much more skilled and adaptable labour force, which has enabled it to dominate the market for better grades of hessian, particularly linoleum hessian. Cloth for backing linoleum must be particularly free from faults and free even from crinkles which might occur during packing or in transit. The production of perfect "pieces" six feet wide and 2,000 yards long requires skill and care of a higher order than will suffice for sacking. The lack of integration in Dundee, where spinning, weaving, and finishing are commonly carried out in separate establishments, even when these are under the same ownership, adds to the flexibility of the industry. Dundee factories are prepared to turn over labour from one cloth to another and are prepared to accept contracts on more elastic terms and for smaller quantities than those in Calcutta, whose system is most efficient when labour and machinery are engaged continuously on the production of the same cloth. Dundee business is thus being more and more confined to specialities which India could produce if necessary but which will probably be left to Dundee so long as a market can be found for the types of goods already produced. Any serious contraction of the market for Indian goods, however, would be likely to lead to an intensification of competition with Dundee.

A similar result might be brought about if the demand for jute goods remained stationary and productive capacity in India increased, and such a development has been threatened during the past three or four years. Since its foundation in 1884 the Indian Jute Mills Association has met temporary

declines in demand by restriction of output through reductions of working hours. In 1931 the members of the Association agreed to seal a certain proportion of their looms and to restrict the weekly number of hours the mills should work in order to maintain prices. The policy was changed in 1934 because mills outside the Association were extending production. In November 1934, under the agreement, the unsealing of looms began, and between April 1936 and March 1937 restrictions on working hours were removed. Instead of a complete return to the multi-shift system, most of the mills in the Association worked 54 hours a week instead of 40 as formerly. Some mills were working as many as 108 hours weekly. The policy was designed to coerce the mills outside the Association into joining a restriction agreement by forcing prices down to a level which was unprofitable to them. At the same time it inflicted considerable hardship on the higher cost producers of Dundee. The policy has succeeded in bringing about an agreement between all but a negligible proportion of producers in India and includes an arrangement for a boycott of firms which either sell to or buy from mills which are not parties to it. The threat to the Dundee industry from still further increased Indian output is thus temporarily removed, and at present the A.R.P. demand for sandbags is producing something approaching boom conditions, but in the long run its existence depends on how far it pays India to maintain an attitude of " live and let live " towards it. In certain ways it pays India that there should be an industry in Dundee. The same firms supply both with machinery ; new machines can be tried out in Dundee while Calcutta watches the results ; and Dundee also serves as a training ground for managerial personnel, but there are limits to the price India is willing to pay for these advantages.

During the present decade Dundee has thus been faced with first an unparalleled slump and then greatly intensified competition, while the trend of prices of jute goods has been downward for nearly 15 years. In the face of these adverse factors the industry has tried to reduce costs. Labour costs being a high proportion of total costs, these were the obvious point of attack. According to the Census of Production of 1935, the net output of the jute industry, i.e. the difference between the value of gross output and the cost of raw materials, fuel, and power, was £2,906,000, or £120 per person employed. The proportion of net output represented by wages was 69 per cent., compared with 85 per cent. in 1930. The average wage in 1935 was thus rather less than £83 a year. Wages are fixed by a Trade Board, and their level is influenced considerably by the level of Unemployment benefits and allowances. Wages being relatively rigid, the only available method to reduce wage costs has been through technical changes.* These have, however, been confined to the preparing and spinning section, where a movement to adopt new methods began in 1927 but was greatly accelerated after 1932. Labour has been displaced directly by the introduction of automatic can trampers and sliver roll formers to pack the sliver as it leaves the carding machines and drawing frames. The practice of giving each spinner two frames to mind instead of one, which although dating from pre-war days became almost universal during the slump years, reduced the number of spinners, who are relatively

*I am indebted to an unpublished paper by Mr Dennis Chapman for data concerning recent technical changes.

highly paid. The demand for juvenile female labour has been reduced by the elimination of the squads of girls who used to replace full bobbins by empty ones. Labour has been indirectly eliminated by the speeding up of all machinery and increasing the capacity of cans and bobbins.

These technical changes involved heavy expenditure on new machinery, and in order to cut capital costs a shift system was introduced. The availability of cheap electricity during the night was also a factor in favour of night shifts. Some indication of the amount of technical change can be obtained from the fact that the industry consumed twice as much electricity in 1935 as in 1930, although the total yarn output was barely 10 per cent. greater. Several modifications of the shift system are in operation. Where men are working alternately on day and night shifts, a few boys are employed during the daytime and women on the day shift do the winding for both shifts. In one case men over the age of 21 form 65 per cent. of the labour force, and only 15 per cent. of female labour is used ; a complete contrast to the old system where few adult men were employed. Another modification is to run the day shift on traditional lines with boys under 18 and women and to use young men 18-21 on the night shift. The shift system is still in the experimental stage, and the night shift is unpopular with young workers ; housing conditions in Dundee make adequate daytime sleep very difficult to obtain. In some cases the rate of labour turnover is believed to be very high. Some degree of compulsion is exercised through the loss of six weeks' employment benefit which follows from leaving a job without reasonable excuse.

The effect of these changes has been to increase the proportion of males to females *actually employed* from 1 : 2·1 in 1924 and 1 : 2·5 in 1930, to 1 : 1·7 in 1935. The proportion of juvenile labour has likewise fallen, for males from 1 in 4 in 1924 to 1 in 5 in 1935, and for females from 1 in 6 to 1 in 7. Until the early 1930's Dundee had a serious problem of unemployment among young men who had been dismissed at the age of 18 when they became eligible for the next grade in the Trade Board wage scale. They had little chance of ever being employed in the jute industry again. Under the new system fewer boys are taken on at school-leaving age and at 18 they are offered jobs on the night shift. There is a likelihood under the new arrangement that in future men will be thrown out of employment at 21 if the supply of men between 18 and 21 suffices for the night shift, but although the problem exists it is not important as yet.

These technical changes have been accompanied both by a reduction in the numbers of workers nominally attached to the industry and by heavy unemployment. In 1930 some 41,000 persons aged 16-64 were registered as jute workers under the Unemployment Acts, and of these approximately 35,000 were in Dundee. Corresponding figures for 1938 were 28,000 for the industry and rather more than 24,000 in Dundee. Most of the reduction in the numbers of insured persons is accounted for by a fall in the number of insured females, which may be partly attributed to the operation of the Unemployment Insurance Anomalies Act, which caused many married women to drop out of the unemployment statistics. In 1931 there were 12,380 insured males and 27,770 insured females, while in 1938, excluding juveniles, there were 10,760 males and 17,220 females, so that the number of males has fallen only 13 per cent. compared with a fall of 38 per cent. in the number of females. This decline in numbers has been accompanied by heavy unemploy-

ment. From February 1930 until June 1933 the percentage unemployed was never less than 30; the average for 1931 was nearly 50 per cent., and in that year and again in 1932 extended holiday periods raised the percentage to over 70. At the time of writing (March 1939) some 20 per cent. are unemployed despite the high level of activity in the industry, and this figure may be taken to represent the surplus of labour which still exists.

The industry has thus made considerable efforts and labour has suffered severely in the process of adaptation to changed conditions, but events have moved still more rapidly. Still more contraction is probably necessary before an uneasy equilibrium is reached at that level of output which Calcutta is at present willing to leave to Dundee. Both a tariff and a quota system have been advocated as a means of maintaining the present level of output, but both now appear to be ruled out for the next five years by the Anglo-Indian Trade Agreement. In any case, a quota would probably be unacceptable to the Government, which has been unable to place all the sandbag orders it was willing to give to Dundee. It would deprive home consumers of supplies which at present Dundee could not produce, and further, it would certainly invoke coercive competition from Calcutta in the export market in those lines where Dundee now encounters little rivalry. Potential losses of trade in the export market are at least as great as any probable gains in the home market. The same argument applies, but to a lesser extent, to the use of a tariff. It would be necessary to find a level of tariff which would give a profit margin sufficient to prevent further contraction of the industry and yet which would not reduce the trade of the Indian mills sufficiently to cause them to take retaliatory action. At present the industry feels itself precariously balanced on the edge of a precipice and, if it falls over, the city of Dundee will be largely dependent on Unemployment relief.

XI.

GOVERNMENT AND PEOPLE—SOCIAL SERVICES

BY

DAVID LATTO, Town Clerk, Dundee.

The development of the social services in this country has been probably the greatest feature of national life since the beginning of the present century. To define exactly what is meant by the term "social services" would be rather difficult, and in the Report of the Committee on National Expenditure published in 1931 (the May Report) it is stated that "no clear definition of the category of social services has ever been laid down." The services covered by the term, however, are sufficiently well known to render any attempt at an exhaustive definition unnecessary, and they may be grouped roughly under three heads :—

(a) Relief of destitution ;
(b) Provision of health services (including housing) ; and
(c) Provision of education and educational facilities.

The first is clearly a social service, and the other services may be described as social in that they are provided for the recipients irrespective of ability to pay for them, the only qualification being need.

The social services are provided by the central government, or by the local government, either with or without State aid. The services provided by the central government are, with two exceptions, based on a scheme of insurance, or quasi-insurance, the benefits being granted primarily not by reference to the needs of the recipient, but in return for contributions paid and, in certain cases, varying in amount according to the contributions paid. The principal schemes of this class are unemployment insurance, national health insurance, and contributory widows' and orphans' and old age pensions schemes. These schemes, however, though based on the principle of insurance, confer benefits on the recipients on a scale far in excess of what would be covered by an ordinary insurance, on an economic basis, of the risk involved. The major schemes of unemployment insurance and national health insurance are confined to the wage or low salary earning classes, and while it is only the employee who receives the benefits, the schemes are maintained by contributions, not only from the employee, but from the State and the employer, so that these schemes are also social services in substance if not in form.

The two exceptions of the government schemes which are not based on insurance are (a) Old Age Pensions under the original Act of 1908, and the extension of that Act to Blind Persons of 50 years of age by the Blind Persons Act of 1920 (the age being reduced to 40 by the 1938 Act), and (b) Unemployment Assistance under the Unemployment Assistance Act, 1934.

It is principally with the social services provided by the local government authorities that I propose to deal. It would be impossible for me to deal with all the aspects of the question or to go into major questions of policy, and I propose merely to discuss the administration of the various services.

(a) Relief of Destitution.

The relief of destitution is the principal social service, and the other services are, to a considerable extent, branches of it, but all the services have developed to such an extent that each must now be regarded as a separate entity.

The relief of destitution is a service which had its beginning long before the twentieth century. In Scotland the maintenance of the poor from local rates was instituted by the Act of the Scots Parliament, 1579, c. 74, which authorised the levying of a tax in every parish for the support of the aged and impotent poor. The granting of relief to able-bodied poor was not authorised under the earlier Poor Law Acts. This system continued as the basis of Scottish Poor Law down to 1921, when the tremendous increase in unemployment consequent on the post-war depression led to the passing of the Poor Law (Emergency Provisions) (Scotland) Act, 1921, which extended the granting of relief to able-bodied persons provided they were destitute and unable to obtain employment. In 1930 the Local Government Act of the previous year abolished the parish as the unit of administration and substituted the city, county, and large burgh, thereby equalising the burden. The Poor Law (Emergency Provisions) (Scotland) Act, 1921, was passed as a temporary measure, and was renewed from year to year down to 1934, when its provisions became permanent under the Poor Law (Scotland) Act, 1934.

The relief of the poor by local authorities under the Poor Law Acts is not assisted by the State, and is the only major social service administered by the local authorities which is not so assisted, but the burden of this expenditure on local rates was lightened considerably by the Government in 1936 when the Unemployment Assistance Board, established in 1934, took over the relief of the able-bodied poor who were still normally in employment covered by the Health Insurance Acts.

Relief by the public assistance authority is granted either by way of outdoor relief—a weekly cash payment to the recipient (supplemented by grants of clothing and, where necessary, medical benefits) or indoor relief—maintenance in an institution. Outdoor relief is the more usual form of assistance, and indoor relief is generally only provided where the applicant requires care and attention which can only be provided in an institution or where the habits of the applicant are such that the grant of outdoor relief is undesirable, as, for example, the case of the habitual drunkard.

The institutions provided by the public assistance authorities consist of the poorhouse and the poor law hospital. In the case of the larger authorities these are separate institutions, but in the smaller areas there is usually only one building, with separate blocks or wards. The larger authorities also provide separate institutions for children to ensure their being kept apart from the environment of the poorhouse. The poor law hospitals were originally provided solely for the treatment of poor persons requiring medical care and treatment. Section 27 of the Local Government (Scotland) Act, 1929,

however, empowered local authorities to make available general hospital treatment apart from the poor law and enabled them to provide, in their poor law hospitals, for persons not in receipt of public assistance, or to build additional hospital accommodation. Prior to the Act local authorities had only power, apart from the Poor Law, to provide accommodation for specific infectious diseases (mental hospitals prior to the Act were provided by District Boards of Control which were superseded by the local authorities in the cities and counties). Where the local authorities have made their poor law hospitals available as general hospitals, however, they must make a charge for treatment in the case of patients other than persons receiving poor relief, whereas in the infectious diseases hospitals treatment is provided free. The intention of Section 27, in empowering local authorities to provide general hospital facilities, was principally to relieve the pressure on the voluntary hospitals, but, apart from the four cities and one county, no provision for this public health service has yet been made. The place which these hospitals will take in the general scheme of hospital services has not yet been clearly defined, but it is probable that in the future local authorities, at least in the cities, will be required to provide general hospitals for the treatment of sub-acute and chronic cases requiring routine medical and nursing attention and leave the voluntary hospitals to deal with cases involving specialised medical or surgical treatment.

This part possibly relates more to public health than public assistance, but I have dealt with it in this section because of the fact that it has developed from the poor law services.

(b) Provision of Health Services.

The origin of the public health services in this country probably dates from about the middle of last century, but it was not until the beginning of the present century that they developed as social services. The original public health services were directed principally towards the provision of sanitation, the removal of nuisances, and the control and treatment of infectious diseases, not from the point of view of the health of the sick, but for the protection of the community at large.

The safeguarding of the health of the community at large still forms the basis of the health services, but along with this there has developed the idea of public health as a social service, and most of the public health services provide an intermingling of both principles. An example of this will be found in the development and extension of the treatment of tuberculosis. The general provision of sanatoria by local authorities dates from about 1906, but these institutions at the beginning could do little more than prevent the spread of infection by the segregation of sufferers from the disease. Since that date these institutions, with the advance of medical science, have been increasingly successful in effecting cures, and within recent years many of the sanatoria have gone even further by training patients in some new occupation of a congenial type in which they may engage on leaving the institution without detriment to their condition and in which they will be able to earn a livelihood.

The power of local authorities to provide for the prevention and treatment of infectious diseases was conferred by the Public Health (Scotland) Act, 1897. The school health services were originally provided for under the

Education (Scotland) Act, 1908, but these services did not come under the control of the local public health authorities until 1930, so that, so far as the local authorities' health services are concerned, the next statutory developments may be taken as the Notification of Births (Extension) Act, 1915, which authorised the local authorities to make arrangements for attending to the health of expectant and nursing mothers and of children under five years of age, and the Maternity and Child Welfare Act, 1918, which authorised the erection of maternity hospitals. In addition, the Midwives Act of 1915 conferred powers on local authorities with regard to the provision of medical assistance in case of emergencies arising at confinements, and the Maternity Services (Scotland) Act, 1937, provided for the establishment of a complete domicilary service, including a medical practitioner and a midwife, with the assistance of an expert obstetrician, if necessary.

In connection with the administration of maternity and child welfare schemes, there are provided clinics where advice is given by medical officers of the local authorities to expectant and nursing mothers, and home visitations are made by health visitors employed by the local authorities.

In addition to the provision of medical and nursing facilities, the local authorities also provide food and milk under the Maternity and Child Welfare Schemes to mothers and children who are found to require additional nourishment for the maintenance of their health.

The school medical services now form a very important part of the health services of the local authority. As already stated, provision for these services was made by the Education (Scotland) Act, 1908. The 1908 Act authorised School Boards to conduct the medical inspection and supervision of school children, and the Education (Scotland) Act, 1913, authorised them to provide treatment. The powers of the School Boards were transferred to Education Authorities in 1919, and in 1930 *ad hoc* Education Authorities were superseded by the County Councils, and the Town Councils of the four cities (Edinburgh, Glasgow, Aberdeen, and Dundee).

The following quotation from the Report of the Departmental Committee on Scottish Health Services (1936—Cmd. 5204) describes fully the present scope and extent of the school medical services :—

" The scope and aims of this service were defined in a joint memorandum issued by the Department of Health for Scotland and the Scottish Education Department in 1929 as follows :—

" (a) To provide such conditions of school life as will, as far as possible, secure healthy growth and development and prevent sickness and incapacity among school children.

" (b) To provide for the systematic medical examination of school children and their supervision throughout school life.

" (c) To follow up and keep under supervision all children found to be suffering from physical or mental defect.

" (d) To provide appropriate treatment for the children of necessitous parents, and to secure that all parents shall have their children treated when necessary, whether privately or at the public expense."

" The following is a summary note of the arrangements made under school health schemes :—

" In the course of a child's attendance at school three routine medical examinations are carried out, generally at ages 5 to 6, 9 to 10, and 13 ; a test

of vision is usually made at age 7. An additional examination is made of children continuing at secondary schools. Re-examinations are made of children found with defects, and special examinations of children put forward by parents, teachers, or school nurses. In one area, the examination of the age group 9-10 is omitted and an annual classroom survey of all children is made by the medical officers with the co-operation of the teachers; children who then appear to require a fuller examination are referred for medical examination.

"Parents are notified of conditions that require treatment and are recommended to seek the advice of the family doctor. For children of necessitous parents treatment is provided by the local authority either at a centre or by other arrangement. A system of 'following-up' by school nurses is in operation. These nurses visit the houses and urge the parents to obtain the necessary treatment for their children, explaining the facilities available.

"Provision varying in kind and in adequacy is made by local authorities for the suitable education of exceptional children (physically or mentally defective, blind, partly blind, deaf and dumb, epileptics, etc.) in ordinary schools or special schools and by arrangement with voluntary organisations.

"Other activities under the school health service include the following:—Assistance with arrangements for feeding school children and securing that such arrangements are made where necessary; the supervision and control of the hygiene of the schools; advising on the structure or internal arrangements of schools which affect the health of the pupils and, where consulted, on school sites and playgrounds; the supervision of physical education, instruction in personal hygiene, co-operation with the other public health services."

Provision is now also made for the examination of the child before leaving school to determine his suitability or otherwise for certain classes of employment, and a copy of the report of this examination is sent to the Local Committee for Juvenile Employment. In addition, the school health records of pupils are transmitted to the Health Insurance Committee so that the medical history of the pupil is available for the use of his panel doctor when he enters insurable employment.

The public health services have grown considerably during the last twenty years, and all tendencies at present point to a still further development in the future both by extension of the existing services and provision of new services, such as that introduced by the Cancer Act, 1939, under which local authorities are bound to make arrangements for securing that facilities for the treatment of persons suffering from cancer are adequate for the needs of their areas.

It would be very difficult to forecast on what lines development and expansion will take place, but co-ordination of the work of local authorities' hospitals and the voluntary hospitals will probably be dealt with in the near future and provision made for filling in the gaps which at present exist between the child welfare schemes and the school medical services. There are at present in Dundee two nursery schools for children between the ages of two and five, and it is probable that in the future nursery schools will provide for children between two and seven years of age, and thus cover the period included at present in the infant department of the primary schools.

Schemes for the welfare of the blind under the Blind Persons Acts of 1920 and 1938 are also administered by the local authorities as part of the public health services, provision being made for the training of blind persons and for the maintenance of the necessitous blind. In addition, under the latter Act necessitous blind persons are also granted an allowance for their dependents, so obviating the necessity of such dependents having to resort to public assistance.

In dealing with the social services of the local authorities I have not so far dealt with the housing question. Housing and environment play an important part in the social services, and the fact that I do not discuss the housing question at length is not because I minimise its importance, but because the question is so large that it would be quite impossible to deal with it adequately within the limits of this article. However, I should perhaps relate briefly the development of post-war housing.

The complete cessation of house-building during the war led to a very acute housing shortage in the immediate post-war period, and in 1919 the Government passed an Act enabling local authorities to proceed with the erection of houses with the assistance of a government grant. The high cost of building at that time would have made the rents of the houses prohibitive had they been fixed on an economic basis, and it was accordingly necessary to provide a subsidy. Towards this subsidy the local authority provided a sum equal to the produce of a rate of four-fifths of a penny per pound, and the Government provided the balance, the Government contribution being by far the greater share of the deficit.

Subsequent housing legislation was directed mainly towards the clearing out of slum areas, the Acts of 1923, 1925, and 1930 making provision for the erection by the local authority of houses for persons living in properties unfit for human habitation. The Housing Act of 1935 went further by providing for the rehousing of persons living in overcrowded conditions, so that in the eradication of the slums and the relief of overcrowding the provision of housing accommodation has now become one of the principal health services of the local authorities. Towards the cost of the erection of houses for persons living in slums or in overcrowded conditions the local authorities receive subsidies from the Government and they themselves also contribute towards the cost.

(c) Provision of Education and Educational Facilities.

The provision of education by the local authorities may probably be regarded as one of the social services, but I do not intend to deal with the provision of education itself, but with the provision of educational facilities, i.e. the facilities provided by the local authority to enable the child to take full advantage of education provided.

By the Education (Scotland) Act, 1908, where parents are unable by reason of poverty or ill-health to supply sufficient and proper food or clothing for their child, the school boards were authorised to make such provision for the child as they might deem necessary during the period the child was under obligation to attend school.

The Act also authorised the payment from the education fund of expenses incurred in bringing opportunities for education within easier reach of children in outlying parts of their district, either by providing means of conveyance,

or paying travelling expenses for teachers or pupils to and from their homes, or defraying the cost of lodging pupils in convenient proximity to a school.

Special provision was also made in this and other Acts for the education in special schools, homes, or other institutions of blind, deaf-mute, epileptic, crippled, or defective children.

The Education (Scotland) Act, 1918, empowered education authorities, with a view to securing that no child who is qualified for attendance at a secondary school and who, from the reports of the teachers, is likely to profit thereby, shall be debarred by reason of expense, to grant assistance to such child by payment of travelling expenses or fees, or cost of residence in a hostel, or of a bursary or maintenance allowance, and the authorities were also authorised to assist any adult qualified person in their area to attend a university or other central institution for higher education.

Under the Milk in Schools Scheme of the Milk Marketing Board, as approved by the Scottish Education Department, milk is supplied by the Milk Marketing Board to children in schools at one half of the ordinary rate, and in many cases the Education Authorities arrange for the provision of milk in necessitous cases entirely free under the general authority of the 1908 Act.

This paper is intended to be informative only, but on the assumption that every child coming into this world is entitled to find reasonable opportunity to live a healthy and happy life, the natural extension of the social services will suggest itself to every member of the British Association and, in particular, to those of them who are members of local authorities.

XII.

EDUCATION IN DUNDEE

BY

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Dundee can scarcely be ranked as one of the distinctive cultural centres of Scotland. For such a distinction Edinburgh and Aberdeen have stronger claims. Yet it would be a mistake to undervalue Dundee in this connexion. It has to be remembered that the city stands somewhat apart from the main centres of population. If its institutions of higher learning were late in development, that is due in part to the isolated position of the city, in part also to the fact that in the near neighbourhood the ancient University of St. Andrews provided adequately enough for the cultural needs of the district.

The High School.

The early history of education in Dundee centres round the story of the old Burgh or Grammar School, now represented by its direct successor, the present High School of Dundee. Dundee has always been amongst the most important of Scottish towns. It was one of the first towns to develop a continental trade, its favourable situation on the edge of the fertile Carse of Gowrie giving it a certain advantage which its merchants knew how to exploit. Historical records make it clear that the Scottish burghs early showed an interest in education. Most of them seem to have been provided with grammar schools before the end of the thirteenth century.

The Dundee Burgh School dates from the reign of Alexander II. The precise year of opening is a matter of conjecture, but it is at least 700 years old. A document exists (*circa* 1220 A.D.) in which the Bishop of Brechin grants to the Abbot of Lindores permission to open a school, and we know from later references that the permission was acted upon. If Blind Harry is to be relied upon, Sir William Wallace was a pupil of the school. In 1434 we read of a certain schoolmaster of Dundee who was dismissed at the instance of the Bishop of Brechin because he had ignored the Bishop's orders. At a later date the burgh schoolmaster got into trouble with the Church authorities for spreading the Lutheran heresy among his pupils. In this he seems to have had the backing of the magistrates, well known for their sympathetic attitude to the reformed doctrines.

The school had a considerable reputation for the teaching of Latin. The usual course in the grammar schools in Scotland extended over five years, but for a considerable time Dundee undertook an ambitious seven years' course. The method in use was the direct method, Latin being still regarded as a living speech, and the writings of scholars like Erasmus and George Buchanan being placed on an equal footing with the works of Cicero and Virgil. Among distinguished pupils of these early days were Hector Boece, historian, and first Principal of Aberdeen University, and Sir George Mackenzie, founder of the Advocates' Library in Edinburgh. The classical tradition established in early times has been worthily maintained by the school up to the present day, as the records of Edinburgh and St. Andrews Universities clearly show.

The Sang Schule.

Burghs in Scotland acknowledged the obligation of supporting only two schools—the Grammar School and the Sang Schule. Before the Reformation the Dundee Sang Schule stood near the Parish Church at the south-west corner of what was then known as School Wynd, now South Lindsay Street. We know little about it, but the reference to Sir John Fethy, a master of the Sang Schule in 1531, is important, since that musician is recorded by Wood in his Psalter of 1566 as being "the first organeist that ever brought into Scotland the curius new fingering and playing on organs." Fethy must have been a first-rate musician, for he received similar appointments later in Aberdeen and Edinburgh. At the time of the Reformation the Sang Schule was "roupit" by order of the Council, but we find in 1584 that it had been restored with John Williamson as its master as an elementary school, in which reading and writing with both vocal and instrumental (the virginalls) music was taught. The sack of the city by Monk in 1651 led to the closing of the school for a time, but it appears again in 1652, when George Runsiman was appointed its master. During the eighteenth century the prosperity of the school varied with the capability of its masters, who, in some cases, let the standard of music teaching fall or were unpopular owing to their political opinions. Until the early years of the eighteenth century the Mastership of the Sang Schule carried with it the precentorship in the Parish Church, but, by the third decade, we find masters in other schools obtaining the precentorship. The Council gradually gave up its insistence on the monopoly of the music school in the teaching of the art, especially when professional musicians became more numerous, and the Sang Schule merged into one or other of the schools of the burgh.

The English School and the Dundee Academy.

The magistrates of Dundee, while they maintained the old grammar school, were not insensitive to the demand that characterised the middle and latter half of the eighteenth century for a less narrow type of education. To meet the demand for something more than the standard curriculum of Latin, Greek, and Mathematics offered by the grammar school, the Town Council, in the year 1702, founded the English School for the study of English, reading, writing, and book-keeping. In the latter half of the century they opened, in 1786, a third school, the Dundee Academy. Classics was excluded from the curriculum, but French provided a reasonable substitute, and Italian, drawing, and applied mathematics were included. One of the teachers was James, afterwards Sir James, Ivory, the distinguished mathematician. It is on record that one of the magistrates, when he learned that a new and mysterious subject called Algebra was being taught, proposed "to put Jamie Ivory awa', as they had already a guid enough teacher of the alphabet."

At the end of the eighteenth century, therefore, Dundee had three schools for secondary education, and it soon became apparent that it was unnecessary to maintain all three. They were ultimately combined and housed in the present handsome building at the top of Reform Street. The joint school was known as the Public Seminaries, but this somewhat unsuitable name was abandoned later and the present name, the High School of Dundee, was substituted.

In normal circumstances the High School would have passed into the charge of the School Board after the passing of the Education Act of 1872. As a matter of fact, the School Board actually did lay claim to the school, but one of the magistrates, Bailie William Harris, offered the School Board the sum of £10,000 if they would forego their claim. With this money the School Board built a secondary school, the Harris Academy, and Bailie Harris then gave a further sum of £20,000 to the High School. The arrangement was embodied in an Act of Parliament under which a directorate was appointed for the High School. Under Bailie Harris' will an additional sum of £25,000 became available, and with this sum the Girls' High School was built.

Secondary Schools.

Besides the High School, Dundee possesses two other large secondary schools, Morgan Academy and Harris Academy, and two smaller ones, Grove Academy and Lawside Secondary School, the latter a Roman Catholic school. Morgan Academy, originally Morgan Hospital, was erected in 1868 for the accommodation of 100 boys, in accordance with the will of Mr John Morgan, a native of the city. At a later date the Educational Endowments Commissioners recommended that the terms of the Morgan Trust be departed from, and the buildings were acquired by the Dundee School Board and opened as a secondary school, now known as Morgan Academy. Harris Academy and Morgan Academy are amongst the largest of Scottish secondary schools, and although their history goes back for little more than fifty years, as against the seven centuries of the High School, they have already built up a splendid reputation and produced an impressive list of old pupils distinguished in the various walks of life.

Central and Other Schools.

In addition to its five secondary schools, Dundee possesses four large central schools, Stobswell, Logie, Rockwell, and St. John's. With the raising of the age some further addition may be necessary. Already a fifth is nearing completion, together with an extensive annexe to Stobswell, the first of the central schools and one of the first of its kind in Scotland.

In addition to the secondary and central schools, Dundee has 30 primary schools, three special schools, and a nursery school. The school population approaches 27,000, and more than 900 teachers are required to run the schools. At one time there were several good private schools in Dundee. To-day there is only one of standing, Seymour Lodge School for Girls, founded nearly 100 years ago, and still filling a useful place in the educational life of the city.

The provision for the education of the young people of Dundee is thus adequate. For a while Secondary education was hampered by the imposition of fees in all the secondary schools. Fortunately this handicap has now been removed in all schools under the Education Committee, although there is still a good deal of dubiety as to the best method of determining which pupils are best suited for the full Leaving Certificate course and which for the less strenuous standard of the Central Schools. Some of the school buildings are amongst the finest and best equipped in the country. Unfortunately there still remain in use several very unsuitable buildings, the evil heritage of a

parsimonious past, when economy was deemed more important than education. Commercial education, now that a series of National Certificates has been established, is satisfactory, but technical education for young people leaves something to be desired.

Technical Education.

The provision of technical education for young people who have left school is one of the weak points in the educational arrangements of the city. There is only one day continuation class. This is organised by the painting trade in the winter months for its young apprentices. As regards evening continuation classes, boys and girls on leaving day school show a distinct disinclination to join them. A pupil who takes a Day School Higher Certificate, testifying to three years of successful post-qualifying work, may enter the Technical College direct. Those who have not reached this standard must qualify for admission by attending evening continuation classes for two years. The result is that the number of students entering the Technical College is smaller than it might be. A very large proportion of those who enter on a five years' course leading to a National Certificate fail to complete the course. In the opinion of some the standard is too advanced for many of those who enter, and the Education Committee of the city is now organising a Trades School for the purpose of meeting this difficulty. Consultations with representatives of the various trades have been held, and temporary premises have been reserved and adapted for the purpose. This represents the first steps in a movement that is bound to grow if the needs of the city as regards technical education are to be adequately met.

Higher Education.

The institutions for higher education in Dundee are all of recent growth, having been developed within the last 50 years. The city now possesses a University College, a Technical College, a Training College, a School of Art, and a School of Economics. Of these the oldest is the University College, dating from 1883. The relations between the University College and the University of St. Andrews are somewhat complicated. They gave rise to a certain bitter feeling in the early days of the history of the College, and even yet an occasional article or letter in the local press, not always judicious or well-informed, recalls unhappy memories of the friction that characterised the earlier association of University and College.

University College.

The establishment of a University College in Dundee was first suggested by Dr. Boyd Baxter, and at a public meeting in 1874 it was resolved to establish a College to be affiliated to the University of St. Andrews. Some years elapsed before a sufficient endowment was obtained. The sum of £120,000 was subscribed by Miss Baxter of Balgavies, to which Dr. Baxter added a further £10,000, and in all a capital sum of £350,000 was forthcoming. This enabled a start to be made. The College was founded in 1880, and three years later teaching began.

To begin with the College had no University connexion, but in 1886 Edinburgh University agreed that science students from Dundee would be allowed to count two years spent in the University College as part of the three years' attendance required for the Edinburgh degree. St. Andrews followed the example of Edinburgh, accepting the whole curriculum in science, and soon afterwards a special clause in the Universities Act of 1889 provided that the University College should be affiliated to St. Andrews University. All along there had been a certain amount of opposition on the part of various persons interested in the prosperity of St. Andrews, a fear lest the success of the new College might imperil the prospects of the old University. This led to a regrettable occurrence. In 1895, as the result of a legal action initiated by certain supporters of St. Andrews, the union was dissolved, a serious blow for Dundee, whose students began to desert it. Fortunately this unhappy state of affairs lasted for two years only. In 1897 new terms of union were accepted, and the University College became once more an integral part of St. Andrews University, the College retaining its own Council for the control of its finances, but subject to the control of the University in all its academic work.

The College began in 1883 with five professors, but there has been marked development since then. Full degree courses are now provided in Arts, Science, Medicine, Dentistry, and Engineering, and there are in addition classes in Scots Law and Conveyancing. The teaching of law is to be extended this year with a view to the institution of a faculty of law and a law degree.

Technical College.

The Technical College and School of Art was opened in 1911. For many years instruction in Science and Art had been carried on by various interested bodies. The directors of the High School were the pioneers as far as art instruction was concerned. Classes in art were run by them even before the 1867 meeting of the British Association in Dundee, but instruction in science was not available till 1871, when the directors of the Y.M.C.A. formed a Science and Art Committee, and with the help of grants from South Kensington instituted large classes for the instruction of artisans and skilled mechanics.

Sir David Baxter, Bart., of Kilmaron, at his death in 1872 left the sum of £10,000 for erecting a Mechanics' Institute, and a further sum of £10,000 for its endowment. His trustees, deeming the money insufficient, delayed action till 1887, when they made an arrangement with the University College to co-operate in carrying out the scheme. A site in the College grounds was obtained and a Technical Institute erected in 1888. In 1902 the Y.M.C.A. classes and those run by the directors of the High School were stopped, and all technical classes in the city were taken over by the Technical Institute, which was then recognised by the Education Department as a Central Institution. In addition to the new Technical Institute various other buildings had to be used in order to cover the work, and as this led to some inconvenience, steps were taken to provide an adequate institution. Sir William Henderson, the Chairman of the Governors, took the lead in raising the necessary money, and in 1911 the present Technical College and School of Art was erected at a cost of £80,000. Of this sum £10,000 was subscribed by Sir William Ogilvy Dalgleish, and a further £24,000 by various subscribers, the Scottish Education Department providing a grant of £35,000.

School of Art and Duncan Bequest.

Independently of the Technical College and School of Art a very valuable bequest, the Duncan of Jordanstone Bequest, has made it possible to provide and equip a College of Industrial Art. A variety of difficulties has prevented the scheme being put into operation. Mr Duncan died about 40 years ago, and left a sum of money, at present worth £170,000, half of it to provide for the erection of the College and half for its equipment. Under the Educational Endowments Acts of 1928 and 1931, the terms of the bequest have been modified, and plans for the erection of the College have been approved and the work commenced. Under the new arrangement, which has been approved by the Education Department, the present Technical College and the new School of Industrial Art will be controlled by the one body of governors, each College having its own Principal. Provision is made under the Duncan Bequest for the inclusion of a department of domestic art.

Training of Teachers.

Dundee Training College, opened in 1920, is one of the four Scottish centres for the training of teachers. A local training committee had been established in 1899 and had been training teachers for six years when a Minute of Council in 1906 established four Provincial Committees, one for each university centre. The new committee at once took over the responsibilities of the local body as well as those of a St. Andrews committee which had been operating since 1895. The Provincial Committee is representative of the various educational bodies throughout the province, county councils, university, teaching profession, church, and central institutions. The foundation stone of the Training College, a handsome building in Park Place, was laid in 1912, the year of the previous visit of the British Association to Dundee. Owing to interruptions caused by the war, eight years elapsed before teaching began. The College provides training for teachers of every kind, graduate and non-graduate teachers, teachers of Art, Music, Handwork, etc. A special feature of the work is the emphasis laid on the training of teachers for rural schools. There are many small country schools within easy reach of the city, and these are freely and regularly used for the practical training of the students.

A Demonstration School attached to the College provides the students with opportunities for practical and experimental work. There is also a Child Guidance Clinic where difficult children from the city schools are taken in hand. These, with an attractive hostel and a large playing field, complete an equipment suitable in every way for the work the Committee is called upon to undertake.

School of Economics.

The School of Economics was gifted to Dundee by the late George Bonar, Esq., one of the leading jute manufacturers. Mr Bonar, anxious to encourage commercial education, offered the necessary funds to St. Andrews University for the establishment of a Commercial College to be an integral part of the University. He hoped to provide in this way for the higher training of those young men and women who propose to embark on a commercial career. Certain technical difficulties prevented the University accepting the gift in

the form in which it was offered, and when the College was built it was ultimately put under the control of the Dundee Education Committee. It provides for two main classes of students—graduates of the University who seek to enter the higher ranks of commerce, and students in possession of a Leaving Certificate aiming at a commercial diploma. Both types are thus of university standing, and it may yet be possible to affiliate the School to the University. Under its able Principal, it has quickly built up a sound reputation and obtained an established position as a centre for advanced commercial training.

Adult Education.

While there is adequate provision for the higher cultural and professional education of those who seek to specialise, the provision of general adult education is less satisfactory. The city has a deservedly high reputation in music, and the number of dramatic and literary societies bespeaks a definite interest in mental culture generally. The English Association, which now numbers its members all over the Empire, originated in Dundee, and there is still in existence a Greek Club, whose members read through Homer once a year. The Workers Educational Association has a vigorous branch in the city, but it receives less support than might be expected. At one time the subjects most in demand were technical or industrial in their appeal, but there is now a more marked interest in subjects of a cultural type. These, it is interesting to note, seem to appeal to a neglected but very important class of worker, the busy housewife, immersed in domestic duties during the day, but eager for self-improvement when the opportunity offers.

XIII.

SCIENTISTS OF THE DUNDEE AREA

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Introduction.

In presenting these biographical notes on scientists of the Dundee area, it is interesting to compare the numbers which fall into the different branches of science.

It will be seen that the general naturalists and botanists predominate. This is perhaps natural when one considers the relatively late development of Dundee as an industrial centre and the wealth and beauty of the countryside surrounding it. It was also probably inevitable that some of the most distinguished of Dundonian scientists should have been drawn south to the great centres of learning there, where their native talents could find greater scope than in their native town. Nevertheless, in Patrick Matthew, George Don, William Gardiner, Charles Lyell, and James Bowman Lindsay, the Dundee area can claim inhabitants who have made their mark in the history of science.

Patrick Blair, M.D., F.R.S., 1666(?)-1728.

Born about 1660 of an old Dundee family, Patrick Blair was a "surgeon-apothecary" and also a keen naturalist. References in his works lead one to suppose that as a young man (1695-97) he was with the army in Flanders. Settled again in Dundee, his position and friendship with the town's Provost lead to his being entrusted with the dissection of the carcase of an elephant which died on the road between Broughty Ferry and Dundee (through no fault of its custodians, as a certificate from the Provost attested). Blair's account of his work—the first dissection of an elephant in Great Britain—was published in the "Philosophical Transactions of the Royal Society of London," Vol. XXVI., for 1710-12, under the title, "Osteographica Elephantina." Over 100 pages of letterpress were accompanied by four copper-plate engravings executed in Dundee under Blair's own eyes. The interest and value of the paper lies not only in its priority, but in the accuracy of the observations.

The acquisition of this elephant inspired Blair to "engage several honourable and learned gentlemen in the neighbourhood, with the physicians and surgeons of this place, to erect a Public Hall at their own private charges, to use all means for improvement of the Natural History, to make a collection of curiosities, wherever they have come a good length, and to establish a Physik Garden, whereof I am overseer."

In 1712 Blair was made an M.D. of Aberdeen. In 1713 he toured the South of England and visited London, to which he returned under less fortunate auspices after the Jacobite rising of 1715. His connexion with the Jacobite sympathisers in Dundee led to his imprisonment in Newgate and to sentence

of death. The influence of his friends, Sloane and Pettiner, secured his pardon and release. He remained in the South after this, first in London and then in Boston (Lincolnshire), where he died in 1728. His principal works are as follows :—

1713—" Osteographia Elephantina " (reprint of R.S. paper).

1718—" Miscellaneous Observations in Physic, Anatomy, Surgery, and Botanicks."

1720—" Botanic Essays," including a discussion on sex in plants, structure of plants, classification, nourishment, and circulation of the sap.

1723-1728—" Pharmaco-Botanologia ; or an Alphabetical and Classical Dissertation on all the *British* Indigenous and Garden Plants of the New London Dispensatory."

George Don, 1764-1814.

According to Knox (Scottish Naturalist, 1883-4), George Don was born in the parish of Menmuir, Forfarshire, in 1764, to Alexander Don and Isobel Fairweather. He was educated at Forfar, and on leaving school apparently spent a brief period with his cousin, gardener at Dupplin. Later he became a clockmaker. The record of his earlier years and wanderings is obscure, and has been pieced together from dates of herbarium specimens. He states himself that he " first began his botanical excursions in the Highlands in 1779." Between 1784 and 1790 he visited Worcestershire, Doncaster, Bristol, Surrey, Essex, London, Oxford. About 1789 he married Caroline Clementina Oliphant Stewart, and about the same time began work as a journeyman in Glasgow, from which centre he continued his botanical excursions. In 1794 he visited Skye, and in 1795 he worked the Clova Hills. In 1797 he purchased the ground called the Dovehillock, near Forfar. Here he built a house and grew vegetables for market, but also constructed a botanical collection, systematically arranged, of native plants. In 1801 and 1802 he explored Lochnagar and the Cairngorms, and in 1802 he was appointed (at a salary of £40) to be the principal gardener of the Royal Botanic Garden, Edinburgh. He did not remain long in Edinburgh (1802-06) ; the meagre stipend was insufficient to keep a large family in the city, and Don loved the freedom of the countryside. Nevertheless, while there he added many plants to the local flora, and in 1803 was made an Associate of the Linnean Society.

Returning to Forfar, he continued his expeditions, but his small business gradually fell away, and he became seriously impoverished. Material conditions did not improve, and in the end of 1813 he returned from an expedition with a severe cold. A suppurating throat followed, and after lingering for six weeks he died on 15th January 1814, in such extreme poverty that he and his family were dependent upon neighbours' charity.

Towards the end of his life and for some time after his death Don's work was the subject of severe and not always unprejudiced criticism. More recent study and revaluation has led to a new appreciation of his pioneer labours. His name is perpetuated in botanical science by the following plants :— Rosa Doniana, Salix Doniana, Agropyron Donianum, Grimmia Doniana, and Seligeria Doniana.

A memorial to Don was erected in Forfar churchyard in 1910 by public subscription raised by the efforts of G. Claridge Druce, John Knox, and the Forfar Field Club.

SIR JAMES IVORY, 1767-1842.

Began life as a flax spinner in Dundee, but turned his attention to mathematics, and after gaining the degree of M.A. taught in the Dundee Academy.

Later he became Mathematical Professor of Sandhurst Military College, Fellow of the Royal Societies of London and Edinburgh, Corresponding Member of the Scientific Societies of Paris and Gottingen, and a Knight of the Order of Hanover.

ROBERT BROWN, 1773-1858.

Robert Brown was born at Montrose, the second son of the Rev. James Brown, an Episcopalian minister. He studied at Marischal College, Aberdeen, and the University of Edinburgh. While still a student he communicated a paper (critical list of additions to Lightfoot's "Flora Scotica") to the Edinburgh Natural History Society. On leaving college he entered military service, and spent some time in Ireland and in London. During his time in London he continued his botanical studies with Sir Joseph Banks, becoming an Associate of the Linnean Society in 1798. He served again in Ireland until 1800, when he was appointed naturalist to an expedition about to be dispatched to survey the Australian coasts. He was with this expedition over four years, during which the southern portion of Tasmania and the southern, eastern, and northern shores of Australia were explored. He returned with large collections (4,200 specimens), of which Brown himself collected and described 3,900. His results and observations are contained in his *Prodromus Florae Novae Hollandiae*, of which the only volume published appeared in 1810. In the same year he became Librarian to the Linnean Society, and in 1811 a Fellow of the Royal Society. In 1822 Brown resigned the Librarianship of the Linnean Society and became a Fellow; in 1823 he became a member of the Linnean Council. In 1827, in fulfilment of the wishes of their original owner, the Library and Herbarium of Banks were incorporated in the British Museum, and Brown was appointed Keeper of its botanical collections, which office he held until his death in 1858.

During this period Brown first became Vice-President (1828) and then President (1849) of the Linnean Society. He received the degree of D.C.L. of Oxford (1832), and became (1833) a Foreign Associate of the French Academy. He received the Royal Prussian Order "Pour le Merite," and a Civil List pension of £200 in recognition of his services to science. The Royal Society bestowed a Copley medal on him in 1839.

Brown's powers did not wane with old age: the work of his later period was as outstanding in quality and extent as his earlier. He joined with a natural genius an extraordinary power of application and a powerful physique which enabled him to describe his plants practically as he collected them, leaving only the finishing touches to be added in the study.

Von Humboldt's description of Brown as "botanicorum facile princeps" was accepted by his contemporaries and his successors, as witnessed by the eulogies of Von Martius (written at his death) and of Hooker some thirty years later.

Patrick Matthew, 1790-1874.

Patrick Matthew was born near Scone in 1790. Educated at Perth Academy and Edinburgh University, he inherited on his father's death the estate of Gourdiehill, near Errol. Matthew was then 17 years of age. He married his cousin, Christian Nicol, in 1817. Matthew travelled extensively on the Continent, in France, the North of Spain, Hamburg, and Holstein, where he purchased an estate. He died at Gourdiehill in 1874.

Matthew was keenly interested in politics and economics, and their relations to forestry and agriculture, of which his own life gave him practical experience. His chief claim to remembrance rests upon his work on "Naval Timber and Arboriculture," published in 1831, and containing in an appendix his views on Natural Selection, in which he anticipated Darwin and Wallace. His claim to priority was fully admitted by Darwin, and an essay by Walther May (Zoologische Annalen, Vol. IV., p. 280, 1911) shows how complete his anticipation really was.

Matthew also published in 1839 a book called "Emigration Fields," and in 1864 a political pamphlet on "Schleswig-Holstein," on whose title page he describes himself as "solver of the problem of species." In 1867 at Dundee he read a paper (not published in the "Report") to the Economics Section of the British Association on "Capital and Labour."

In his latter years Matthew gave much attention to the question of exhaustion of the soil, holding that "high farming and the application of foreign and artificial manures are fast increasing the sterility of our land."

It is perhaps natural that Matthew, living in a time when the direct and indirect effects of war on the human struggle for existence were so evident, should have had his mind focussed upon these problems. His own experience in agriculture would bring before him the effects of natural and artificial selection upon crops and livestock. It is extremely interesting that he should have effected a synthesis of these experiences and arrived at the philosophical conclusions on evolution which he published in "Naval Timber."

Sir Charles Lyell, 1797-1875.

Charles Lyell was born at Kinnordy, near Kirriemuir, in 1797. He studied at Oxford, and his early interest in Geology was encouraged and fostered by Buckland. He became a Fellow of the Geological Society at the early age of 22, and four years later became one of its Secretaries. After leaving the University he returned home for a short period, and found much to interest him in his native county, which had so far been only superficially studied from the geological point of view. He recognised for the first time the anticlinal arch of the Sidlaw Hills and the synclinal trough of the Mearns, and the illustration of the true geological structure of Forfarshire which he gave in his "Elements of Geology" became a classic. His first published paper (1825) was on a dyke of igneous rock discovered near his home. Diggings on the site of a former lake at Kinnordy also gave him material for another paper, comparing recent fresh-water deposits with those of earlier geological periods.

For a dozen years after this period Lyell travelled widely in Europe, contributing no more to Forfarshire geology. In 1840, however, Agassiz announced his belief in the glaciation of Britain. Lyell brought forward new

evidence in support of this contention in his interpretation of two lakes in the Clova Hills. These lakes were found in rocky corries, penned up by mounds of earth and stones, which Lyell described as true glacier-moraines. This marked the beginning of the long series of writings on the Ice Age in Scotland.

All his life Lyell believed in the necessity of first-hand observation over a wide field. In pursuit of this he travelled extensively in Europe, North America, and Canada, seeing for himself the work of others on their own ground, and often by his keen observation detecting errors and noting new evidence.

To his remarkable powers of observation Lyell added a flexible and powerful literary style, which showed itself in all his writings, not least in the classic "Principles" and "Elements" of Geology, and which undoubtedly assisted in establishing the world-wide influence which he has had in placing geology on a firm basis as an observational science.

Patrick Bell, 1799-1869.

Patrick Bell was born in the parish of Auchterhouse, near Dundee, in 1799. While studying for the ministry at the University of St. Andrews he turned his attention to the construction of a mechanical reaper. A machine made to his design was tested on his brother's farm in 1827. Bell did not patent his machine, but it was in regular use until about 1868, when it was placed in the museum of the Patent Office. Although anticipated by Common, who produced in 1812 a machine having the essential principles of the modern reaper, Bell must be considered an independent inventor and one of the pioneers in the making of modern farm machinery. He reported on his invention to the British Association Meeting in Dundee in 1867.

Bell was ordained in 1843, and held the post of parish minister of Carmyllie, Arbroath, until his death in 1869.

He received the honorary LL.D. of St. Andrews.

James Bowman Lindsay, 1799-1862.

Born at Carmyllie in 1799 and apprenticed to a hand-loom weaver, his studious nature finally determined his father to send him to St. Andrews University. He had intended to proceed to the study of divinity, but in 1829 was appointed lecturer in Science and Mathematics in the Watt Institution in Dundee. Later (1841) he was appointed teacher in Dundee Prison at a salary of £50 per annum, a post which he held for 17 years, resigning in 1858 on receiving a government pension of £100 per annum "in recognition of his great learning and extraordinary attainments."

His life interests were divided between philology and electrical science. For more than 25 years he devoted his spare time to a Pentecontaglossal Dictionary, which was well advanced at the time of his death. Subsequently the manuscript was collected and placed in the Dundee Public Library. The "Pentecontaglossal Paternoster, or the Lord's Prayer in Fifty Languages" was published in 1846, and the "Chrono-Astrolabe: a full set of astronomical tables" in 1858.

Lindsay's electrical researches were carried on intermittently with his philological work, and an autobiographical note indicates that between 1832 and 1835 he was working on the problem of electrical light. He states that he

obtained " a constant stream of light " on 25th July 1835. The details of his generator are unfortunately unknown.

In 1843 he proposed a submarine telegraph across the Atlantic after having proved the possibility by a series of experiments.

In a letter to the *Dundee Advertiser* (6/5/1845) he describes an " Autograph Electric Telegraph," in which a cable of 24 wires was to be used (one for each letter of the alphabet), with an ingenious device at the receiving end whereby the magnetic deflection of any wire released a corresponding lettered pith ball, the lettered balls to be collected in sequence in a receiver, and the message read off directly. In the postscript to this letter he suggests that the return current might be sent by sea without any wires, thus proposing wireless telegraphy in theory in 1845, eight years before he demonstrated it by public experiment.

Philology claimed his attention until 1853, when he announced a lecture with experiments on telegraphic communication through water without wires. He demonstrated his method on a larger scale at Carolina Port, Dundee, over a distance of about 120 feet in salt water, and later across the Tay in fresh water. In 1854 he took out a patent for it. In August of the same year he succeeded in sending messages 500 yards across the Mill-dam at Portsmouth. His greatest performance was across the Tay between Dundee and Woodhaven, a distance of about 2 miles. His apparatus consisted (on the transmitting side) of two large immersed plates connected with wires, a galvanic battery, and a commutator for giving the signal; on the receiving side, of two large plates, an induction coil, and the recording apparatus. He found that the strength of transmitted current depended on battery power, surface of immersed sheets, " lateral distance " of immersed sheets, and distance through the water. By suitably increasing the first three he calculated it should be possible to transmit to America. He communicated his experiments to the British Association in Aberdeen in 1859, the title of the paper being " On Telegraphing without Wires," winning the special commendation of Lord Rosse, president of the section.

He carried out further public demonstrations on the Dee and at Liverpool: the latter were not successful, but he succeeded again on the Tay in 1860. This was his last public connexion with the telegraph. In his lectures and his writing he envisaged the general use of electric lighting, power, and communication which are now a commonplace, but which then showed the power of his scientific prevision of the future.

William Gardiner, 1808-1852.

William Gardiner was born at the West Port, Dundee, in 1808. His parents were in humble circumstances, and he was apprenticed to an umbrella-maker. Entirely self-educated, he early showed a leaning towards natural history, which was encouraged by his father and later by a sympathetic employer.

In 1838 he accepted an offer from the Botanical Society of Edinburgh of five guineas for a collection to be made of 2,500 plants from the Perthshire Highlands, an undertaking which was the beginning of his career as a collector, for in 1844 he abandoned his trade and devoted himself entirely to this work. From this time on he supplied extensive and well-prepared collections of

plants to subscribers and others in the United Kingdom and abroad. He became an Associate of the Botanical Society of Edinburgh in 1838, and of the Linnean Society in 1849. In addition to smaller articles and papers, he published "Botanical Rambles in Braemar in 1844, with an Appendix on Forfarshire Botany, 1845," "Twenty Lessons on British Mosses," 1846 and 1849, which included dried specimens.

"The Flora of Forfarshire," 1849. This was Gardiner's principal work, and a curious point arises in connexion with it. A review of the book states that it is "by the author of a Flora of Ten Miles Round Dundee." No record of the publication of this book is known ; but what appears to be a prospectus of such a work exists and was commented on by Sir Joseph Hooker.

Towards the end of his life Gardiner fell into poverty, and a subscription was raised from his clients and correspondents too late to be of help to him. He died of typhus in 1852, and the money subscribed was used for the benefit of his only son.

His botanical collections were acquired by Professor Babington of Cambridge.

PATRICK GEDDES, 1854-1932.

Patrick Geddes was born in Perth in 1854. He was educated at Perth Academy, Royal School of Mines, University College, London ; the Sorbonne, and the Universities of Edinburgh and Montpellier. His early interest in biology, quickened and broadened by extensive travel, became merged in sociology, to which his later life was devoted. He became Professor of Botany in University College, Dundee, in 1888, a post which he held until 1920. Although his formal teaching was confined to the summer term only, nevertheless his vital spirit and personality left its imprint upon generations of students. His talent for "planning" showed itself in the original scheme for the garden at University College, where each line of path had its meaning, and where the beds were planted to illustrate an evolutionary classification as well as to ornament the grounds. No plan or written record of his scheme exists, and on his retiral it fell into disorder, and the radical alterations necessitated by the widening of the Perth Road have swept away most of Geddes' original garden, but the "Philosopher's Walk" of lime trees along the old wall is still there, and the spring beauty of azaleas and bluebells is a reminder of older times.

After his time in Dundee, Geddes became Professor of Sociology and Civics in the University of Bombay, and later Director of the Scots College, Montpellier. This last phase showed an application on an international scale of the ideas which lead to his founding the Outlook Tower in Edinburgh. Geddes' overwhelming desire was to help men to understand themselves in relation to their environment and so to adjust them as to secure betterment for future generations as well as for themselves. In a generation of analysts Geddes strove always towards a synthetic outlook. This attitude informed all his activities. He was a pioneer in regional and town planning, and became president of the Sociological Institutes of London, Edinburgh, and Montpellier.

His publications included books on Evolution and Sex, Biology (with J. Arthur Thomson) ; City Development, Cities in Evolution ; Life and Work of Sir J. C. Bose, etc.

He died at the Scots College, Montpellier, in 1932.

Sir Alfred Ewing, 1855-1935.

James Alfred Ewing was born in Dundee in 1855. He was educated at Dundee High School and the University of Edinburgh. In 1878 he went to Japan as Professor of Mechanical Engineering in the University of Tokyo. In 1883 he returned to his native town as Professor of Engineering at University College, Dundee, and after seven years' service he went to Cambridge to the chair of Mechanism and Applied Mechanics. In 1903 he was offered the post of Director of Naval Education, a post which gave full scope to his genius for administrative work. On the outbreak of war in 1914, Ewing was asked to undertake yet another arduous task, the dealing with enemy cipher. The secrets of this immensely important defence work have never been revealed, even the fact of Ewing's connexion with them was kept secret until long after the end of the war.

In 1916, while still immersed in his war work, Ewing was invited to become Principal and Vice-Chancellor of the University of Edinburgh. When he took office Ewing was 62 years of age, but his untiring zest for work and great bodily vigour enabled him to accomplish great and far-reaching developments in the University during his twelve years there. During this time he saw the establishment of 13 new chairs and numerous lectureships: the institution of the degree of Ph.D.; the erection of new buildings for chemistry, zoology, and animal genetics, and the planning of new departments of geology and engineering. Ewing's skill in securing endowments of over three-quarter million sterling enabled these improvements to be carried through without too great a burden on the University finances.

While carrying on the burden of his administrative duties Ewing was actively engaged on some of the special committees of the Department of Scientific and Industrial Research, notably the Bridge Stress Research Committee, and he still found time for research.

Ewing was much beloved by the students of the University, and his last public appearance was when he delivered an address ("For Better or Worse") to the Affiliated Science Societies in the same engineering classroom where his life's work began sixty years before.

During his life Ewing received many academic distinctions:—LL.D. of Edinburgh, St. Andrews, Glasgow; D.Sc. of Oxford, Durham, Sheffield; Sc.D. of Cambridge; F.R.S., M.Inst.C.E. He received a Royal Medal in 1895 and an Albert Medal in 1929. He was given the freedom of the city of Edinburgh in 1929 and of Dundee in 1933.

During his last years Ewing gave much thought to the ethical bearings of science, which he stressed in his presidential address to the British Association in 1932, and developed in his Hibbert Lecture in Cambridge in 1933, and in his last book, "An Engineer's Outlook" (1933). His creed can be summed up by saying that he took as a personal injunction "*Thou* shalt love thy neighbour as thyself." His publications include:—

"Earthquake Movement," 1883.
"Magnetic Induction in Iron," 1891.
"Steam Engine and Other Heat Engines," 1926.
"Strength of Materials," 1899.
"Mechanical Production of Cold," 1908.
"Thermodynamics for Engineers," 1920.
"An Engineer's Outlook," 1933.

Sir James Walker, 1863-1935.

Born in Dundee in 1863, and educated at Dundee High School, Walker proceeded to the University of Edinburgh, where he graduated D.Sc. in 1886. He went to Leipzig where he studied under Ostwald, receiving the degree of Ph.D. in 1886 for a thesis on the "Affinity Constants of Organic Bases." After three years as assistant to Crum Brown in Edinburgh, he was appointed to the chair of chemistry in University College, Dundee, where he remained until 1908, when he returned to Edinburgh. During his tenure of this chair he saw the erection of the new Department of Chemistry at King's Buildings, completed in 1924. He erected and equipped a most efficient factory for the production of T.N.T. during the war.

He received the Makdougall-Brisbane Medal in 1895, became a Fellow of the Royal Society in 1900, was knighted in 1921, and in the same year became president of the Chemical Society. He received the Davy Medal in 1926, and the Gunning Victoria Jubilee Prize in 1933. He was an LL.D. of the Universities of St. Andrews and Edinburgh. Member of the Universities Grants Committee from 1928-1933.

Although his main interest lay in the field of physical chemistry (his text-book, "Introduction to Physical Chemistry," has passed through ten editions), Walker was also a skilled organic chemist, and his skill in attacking purely technical problems was exceptional.

He was a fine and beloved teacher; his lucidity of exposition created an effect of ease and simplicity in the most difficult subject. As friend, colleague, and teacher, James Walker will not soon be forgotten by those who had the good fortune to work in his department.

PRINTED BY DAVID WINTER & SON, SHORE TERRACE, DUND